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SEPARATION CHARACTERISTICS OF THE ALE-38 CHAFF DISPENSER FROM THE F-4C AND F-4E AIRCRAFT

Janis Kukainis

ARO, Inc.

June 1972

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Janis Kukainis
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FOREWORD

The work reported herein was sponsored by the Air Armament Laboratory (AFATL/DLGC/Lt. J. B. Bechtel), Air Force Systems Command (AFSC), under Program Element 64738F, Project 6510.

The test results presented were obtained by ARO, Inc. (a subsidiary of Sverdrup & Parcel and Associates, Inc.), contract operator of the Arnold Engineering Development Center (AEDC), AFSC, Arnold Air Force Station, Tennessee, under Contract F40600-72-C-0003. The test was conducted on April 12, 1972, under ARO Project No. PC0243. The manuscript was submitted for publication on May 11, 1972.

This technical report has been reviewed and is approved.

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ABSTRACT

A test was conducted in the Aerodynamic Wind Tunnel (4T) to investigate the separation characteristics of the ALE-38 chaff dispenser from the F-4C and F-4E aircraft. Captive-trajectory store-separation data were obtained for four aircraft/weapons loading configurations with store separations from the right-wing inboard pylon of the F-4C and F-4E aircraft. Data were obtained at Mach numbers from 0.42 to 0.90 at a simulated altitude of 5000 ft. At each test Mach number, data were obtained for both full and empty simulated store-model weights. The data obtained show that separation without parent-to-store model contact was achieved at all test conditions.

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NOMENCLATURE

BL	Aircraft buttock line from plane of symmetry, in., model scale
b	Store reference dimension, ft full scale
cg	Center of gravity
C_ℓ	Store rolling-moment coefficient, rolling moment/q_∞Sb
C_{ℓ_p}	Store roll-damping derivative, $dC_\ell/d(pb/2V_\infty)$
C_m	Store pitching-moment coefficient, referenced to the store cg, pitching moment/q_∞Sb
C_{m_q}	Store pitch-damping derivative, $dC_m/d(qb/2V_\infty)$
C_n	Store yawing-moment coefficient, referenced to the store cg, yawing moment/q_∞Sb
C_{n_r}	Store yaw-damping derivative, $dC_n/d(rb/2V_\infty)$
FS	Aircraft fuselage station, in., model scale
F_{Z_1}	Pylon forward ejector force, lb
F_{Z_2}	Pylon aft ejector force, lb
H	Pressure altitude, ft
I_{xx}	Full-scale moment of inertia about the store X_B axis, slugs-ft^2
I_{yy}	Full-scale moment of inertia about the store Y_B axis, slugs-ft^2
I_{zz}	Full-scale moment of inertia about the store Z_B axis, slugs-ft^2
I_{xz}	Full-scale product of inertia, X_B-Z_B axis, slugs-ft^2
M_∞	Free-stream Mach number

m	Full-scale store mass, slugs
p	Store angular velocity about the X_B axis, radians/sec
p_∞	Free-stream static pressure, psfa
q	Store angular velocity about the Y_B axis, radians/sec
q_∞	Free-stream dynamic pressure, psf
r	Store angular velocity about the Z_B axis, radians/sec
S	Store reference area, ft^2, full scale
t	Real trajectory time from initiation of trajectory, sec
V_∞	Free-stream velocity, ft/sec
WL	Aircraft waterline from reference horizontal plane, in., model scale
X	Separation distance of the store cg parallel to the flight axis system X_F direction, ft, full scale measured from the prelaunch position
X_{cg}	Full-scale cg location, ft, from nose of store
X_{L_1}	Forward ejector piston location relative to the store cg, positive forward of store cg, ft, full scale
X_{L_2}	Aft ejector piston location relative to the store cg, positive forward of store cg, ft, full scale
Y	Separation distance of the store cg parallel to the flight-axis system Y_F direction, ft, full scale measured from the prelaunch position
Z	Separation distance of the store cg parallel to the flight-axis system Z_F direction, ft, full scale measured from the prelaunch position
α_p	Parent-aircraft model angle of attack relative to the free-stream velocity vector, deg
θ	Angle between the store longitudinal axis and its projection in the X_F-Y_F plane, positive when store nose is raised as seen by pilot, deg
ψ	Angle between the projection of the store longitudinal axis in the X_F-Y_F plane and the X_F axis, positive when the store nose is to the right as seen by the pilot, deg

ϕ Angle between the projection of the store lateral axis in the Y_F-Z_F plane and the Y_F axis, positive for clockwise rotation when looking upstream, deg

FLIGHT-AXIS SYSTEM COORDINATES

Directions

X_F Parallel to the free-stream wind vector; positive direction is forward as seen by the pilot

Y_F Perpendicular to the X_F and Z_F directions; positive direction is to the right as seen by the pilot

Z_F In the aircraft plane of symmetry, perpendicular to the free-stream wind vector; positive direction is downward

The flight-axis system origin is coincident with the aircraft cg and remains fixed with respect to the parent aircraft during store separation. The X_F, Y_F, and Z_F coordinate axes do not rotate with respect to the initial flight direction and attitude.

STORE BODY-AXIS SYSTEM COORDINATES

Directions

X_B Parallel to the store longitudinal axis; positive direction is upstream in the prelaunch position

Y_B Perpendicular to the store longitudinal axis and parallel to the flight-axis system X_F-Y_F plane when the store is at zero roll angle; positive direction is to the right looking upstream when the store is at zero yaw and roll angles

Z_B Perpendicular to both the X_B and Y_B axes; positive direction is downward as seen by the pilot when the store is at zero pitch and roll angles.

The store body-axis system origin is coincident with the store cg and moves with the store during separation from the parent airplane. The X_B, Y_B, and Z_B coordinate axes rotate with the store in pitch, yaw, and roll so that mass moments of inertia about the three axes are not time-varying quantities.

SECTION I
INTRODUCTION

This investigation was conducted to obtain captive-trajectory store-separation data for the ALE-38 chaff dispenser from the F-4C and F-4E aircraft. During the test, 0.05-scale models of the F-4C, F-4E, and ALE-38 were used. The F-4C and F-4E models were mounted on the main tunnel support, and the ALE-38 model was mounted on the captive trajectory support (CTS) system. Captive-trajectory store-separation data were obtained for four aircraft/weapons loading configurations (Table I, Appendix II) at Mach numbers 0.42, 0.56, 0.66, 0.74, 0.82, and 0.90 at a simulated pressure altitude of 5000 ft. For each test Mach number, data were obtained for both the full and empty ALE-38. The ejector forces used were time-variant functions provided by AFATL.

SECTION II
APPARATUS

2.1 TEST FACILITY

The Aerodynamic Wind Tunnel (4T) is a closed-loop, continuous flow, variable density tunnel in which the Mach number can be varied from 0.1 to 1.3. At all Mach numbers, the stagnation pressure can be varied from 300 to 3700 psfa. The test section is 4 ft square and 12.5 ft long with perforated, variable porosity (0.5- to 10-percent open) walls. It is completely enclosed in a plenum chamber from which the air can be evacuated, allowing part of the tunnel airflow to be removed through the perforated walls of the test section.

For store-separation testing, two separate and independent support systems are used to support the models. The parent aircraft model is inverted in the test section and supported by an offset sting attached to the main pitch sector. The store model is supported by the CTS which extends down from the tunnel top wall and provides store movement (six degrees of freedom) independent of the parent-aircraft model. An isometric drawing of a typical store separation installation is shown in Fig. 1, Appendix I.

Also shown in Fig. 1 is a block diagram of the computer control loop used during testing with the CTS. The analog system and the digital computer work as an integrated unit and, utilizing required input information, control the store model movement. Store positioning is accomplished by use of six individual d-c electric motors. Maximum translational travel of the CTS is ±15 in. from the tunnel centerline in the lateral and vertical directions and 36 in. in the axial direction. Maximum angular displacements are ±45 deg in pitch and yaw and ±360 deg in roll. A more complete description of the test facility can be found in the Test Facilities Handbook.[1] A schematic showing the test section details and the location of the models in the tunnel is shown in Fig. 2.

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[1] Test Facilities Handbook (Ninth Edition). "Propulsion Wind Tunnel Facility, Vol. 4." Arnold Engineering Development Center, July 1971.

2.2 TEST ARTICLES

Models used during this test consisted of 0.05-scale models of the F-4C and F-4E aircraft and the ALE-38 chaff dispenser. Sketches showing the basic dimensions of the F-4C and F-4E models are presented in Figs. 3 and 4, respectively. For this test, only the right wing and fuselage were equipped for pylon attachment. A sketch of the inboard and outboard pylons is presented in Fig. 5. The store mounting surfaces on the inboard and outboard pylons are at -1.0-deg angle of incidence with respect to the aircraft waterline. The 370-gal fuel tank, which was mounted on the outboard pylon, is shown in Fig. 6, and the 600-gal fuel tank with its integral pylon is shown in Fig. 7. A dimensional sketch of the ALE-38 chaff dispenser is presented in Fig. 8, and a photograph of a typical test installation is shown in Fig. 9.

2.3 INSTRUMENTATION

A six-component, internal, strain-gage balance was used to obtain the force and moment data on the ALE-38 model, and translational and angular positions of the store model were obtained from CTS analog outputs. An angular position indicator on the main pitch sector was used to determine the parent-model angle of attack. The inboard pylon was instrumented with a touch wire which aided in the positioning of the sting-mounted store model at the launch position on the pylon. The system was also electrically connected to automatically stop the CTS movement if the store model or sting contacted the pylon or the aircraft-model surface.

SECTION III
TEST DESCRIPTION

3.1 TEST CONDITIONS

For this investigation, separation trajectory data were obtained at Mach numbers 0.46, 0.56, 0.66, 0.74, 0.82, and 0.90. The tunnel Reynolds number was maintained at 4 million per foot. Tunnel stagnation temperature varied between 90 and 115°F.

3.2 TRAJECTORY DATA ACQUISITION

To obtain a trajectory, test conditions were established in the tunnel and the parent model was positioned at the desired angle of attack. The store model was then oriented to a position corresponding to the store carriage location. After the store was set at the desired initial position, operational control of the CTS was switched to the digital computer which controlled the store movement during the trajectory through commands to the CTS analog system (see block diagram, Fig. 1). Data from the wind tunnel, consisting of measured model forces and moments, wind tunnel operating conditions, and CTS rig positions, were input to the digital computer for use in the full-scale trajectory calculations.

The digital computer was programmed to solve the six-degrees-of-freedom equations to calculate the angular and linear displacements of the store relative to the parent aircraft pylon. In general, the program involves using the last two successive measured values of

each static aerodynamic coefficient to predict the magnitude of the coefficients over the next time interval of the trajectory. These predicted values are used to calculate the new position and attitude of the store at the end of the time interval. The CTS is then commanded to move the store model to this new position, and the aerodynamic loads are measured. If these new measurements agree with the predicted values, the process is continued over another time interval of the same magnitude. If the measured and predicted values do not agree within the desired precision, the calculation is repeated over a time interval half the previous value. This process is repeated until a complete trajectory has been obtained.

In applying the wind tunnel data to the calculations of the full-scale store trajectories, the measured forces and moments are reduced to coefficient form and then applied with proper full-scale store dimensions and flight dynamic pressure. Dynamic pressure was calculated using (1) a flight velocity equal to the free-stream velocity component plus the components of store velocity relative to the aircraft and (2) at a density corresponding to the simulated altitude.

The initial portion of each launch trajectory incorporated simulated ejector forces in addition to the measured aerodynamic forces acting on the store. The ejector force functions for the store are presented in Fig. 10. The ejector force was considered to act perpendicular to the pylon mounting surface. The locations of the applied ejector forces and other full-scale store parameters used in the trajectory calculations are listed in Table II, Appendix II.

3.3 CORRECTIONS

Balance, sting, and support deflections caused by the aerodynamic loads on the store models were accounted for in the data reduction program to calculate the true store-model angles. Corrections were also made for model weight tares to calculate the net aerodynamic forces on the store model.

3.4 DATA UNCERTAINTY

Maximum error in the CTS position control was ±0.05 in. for the translational settings, ±0.15 deg for angular displacement settings in pitch and yaw, and ±1.0 deg for angular displacement setting in roll. The trajectory data are subject to variations because of extrapolation tolerances allowed in the trajectory integration procedure. Extrapolation tolerances were ±0.10 for each of the six aerodynamic coefficients measured. Uncertainties in the position of the full-scale store attributable to inaccuracies in balance measurements were calculated assuming negligible bias errors. Based on a 95-percent confidence level, the values at t = 0.1 sec are as follow:

	M_∞	X	Y	Z	θ	ψ	ϕ
Full ALE-38	0.90	±0.01	±0.010	±0.010	±0.05	±0.01	±0.7
Empty ALE-38	0.90	±0.011	±0.016	±0.010	±0.1	±0.20	±1.2

The estimated uncertainty in setting Mach number was ±0.003, and the uncertainty in parent-model angle of attack was estimated to be ±0.1 deg.

SECTION IV
RESULTS AND DISCUSSION

Data showing the linear and angular displacements of the ALE-38 relative to the carriage position on the F-4C and F-4E aircraft are presented as functions of full-scale trajectory time in Figs. 11 through 14. Positive X. Y, and Z displacements (as seen by the pilot) are forward, to the right (outboard), and down. respectively. Positive changes in pitch and yaw (as seen by the pilot) are nose up and nose right (nose outboard), respectively.

At each test Mach number, data were obtained for both full and empty simulated store mass and moment of inertia values. The time-variant ejector force functions for the two simulated store weights are shown in Fig. 10. The ejector forces acted. in each case, in a direction perpendicular to the mounting surface of the inboard pylon.

With the exception of pitch motion at $M_\infty = 0.46$, the empty and full ALE-38 configurations exhibited similar linear and angular motions for all test conditions and all configurations tested. At $M_\infty = 0.46$. the full store pitched nose up, whereas at all other test conditions it pitched nose down. The empty store always pitched nose down, and its pitch and yaw rates were greater than those for the full store. This rapid pitching motion resulted in the early termination of the empty-store trajectories because the store model support made contact with the trailing edge of the parent-aircraft wing. A comparison of Figs. 11 and 12 with Figs. 13 and 14 shows that there are no differences in trajectories from the F-4C and F-4E aircraft with identical wing loadings. The fuel tank location influenced primarily the yaw motion. Nose-outboard movement was greater for the configurations with the centerline tank, and this effect was greatest at the highest Mach numbers. Separation without parent-to-store model contact was achieved at all test conditions.

SECTION V
SUMMARY

Captive-trajectory data were obtained for a 0.05-scale model of the ALE-38 chaff dispenser from the right-wing inboard pylon of F-4C and F-4E aircraft models at Mach numbers from 0.42 to 0.90 at a simulated pressure altitude of 5000 ft. The following observations were made from the significant results of this investigation:

1. The ALE-38 separated from the F-4C and F-4E aircraft without parent-to-store model contact for all aircraft/weapons loading configurations tested.

2. For identical wing loadings. there were no differences in trajectories obtained from the F-4C and F-4E aircraft.

3. The empty ALE-38 exhibited more rapid linear and angular motions than the full ALE-38.

4. The centerline fuel tank location produced greater nose-outboard yaw motion than the outboard fuel tank location.

APPENDIXES

I. ILLUSTRATIONS

II. TABLES

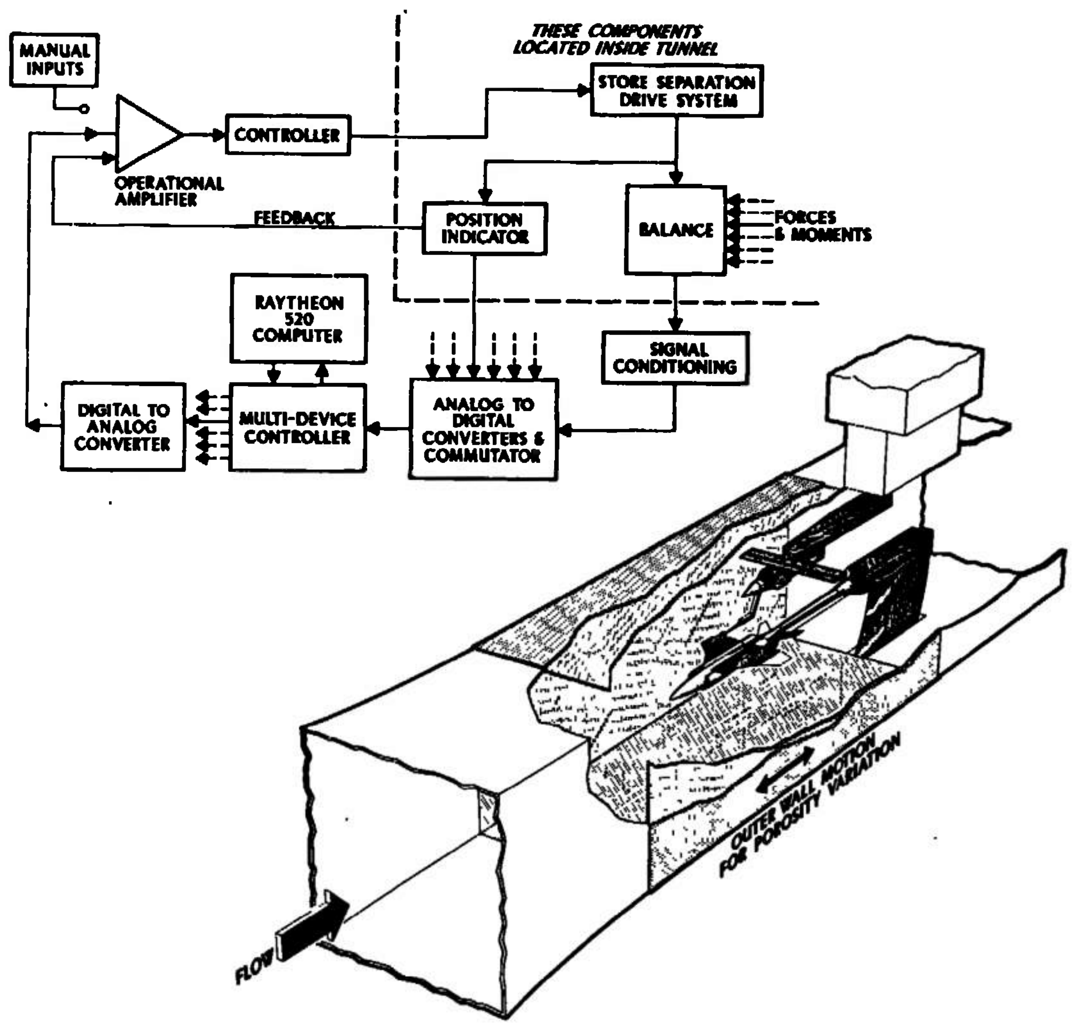


Fig. 1 Isometric Drawing of a Typical Store Separation Installation and a Block Diagram of the Computer Control Loop

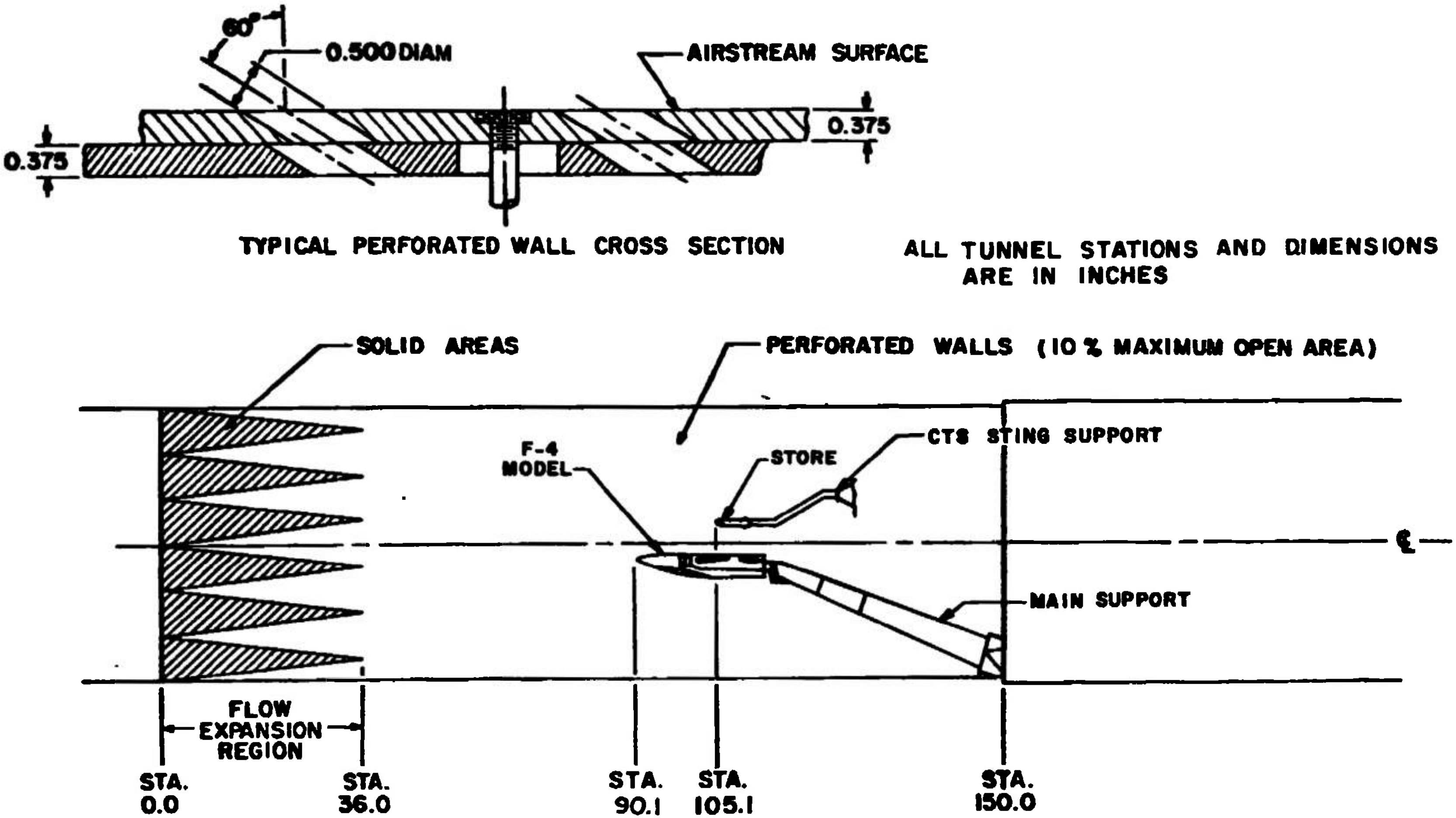


Fig. 2 Schematic of Tunnel Test Section Showing Model Location

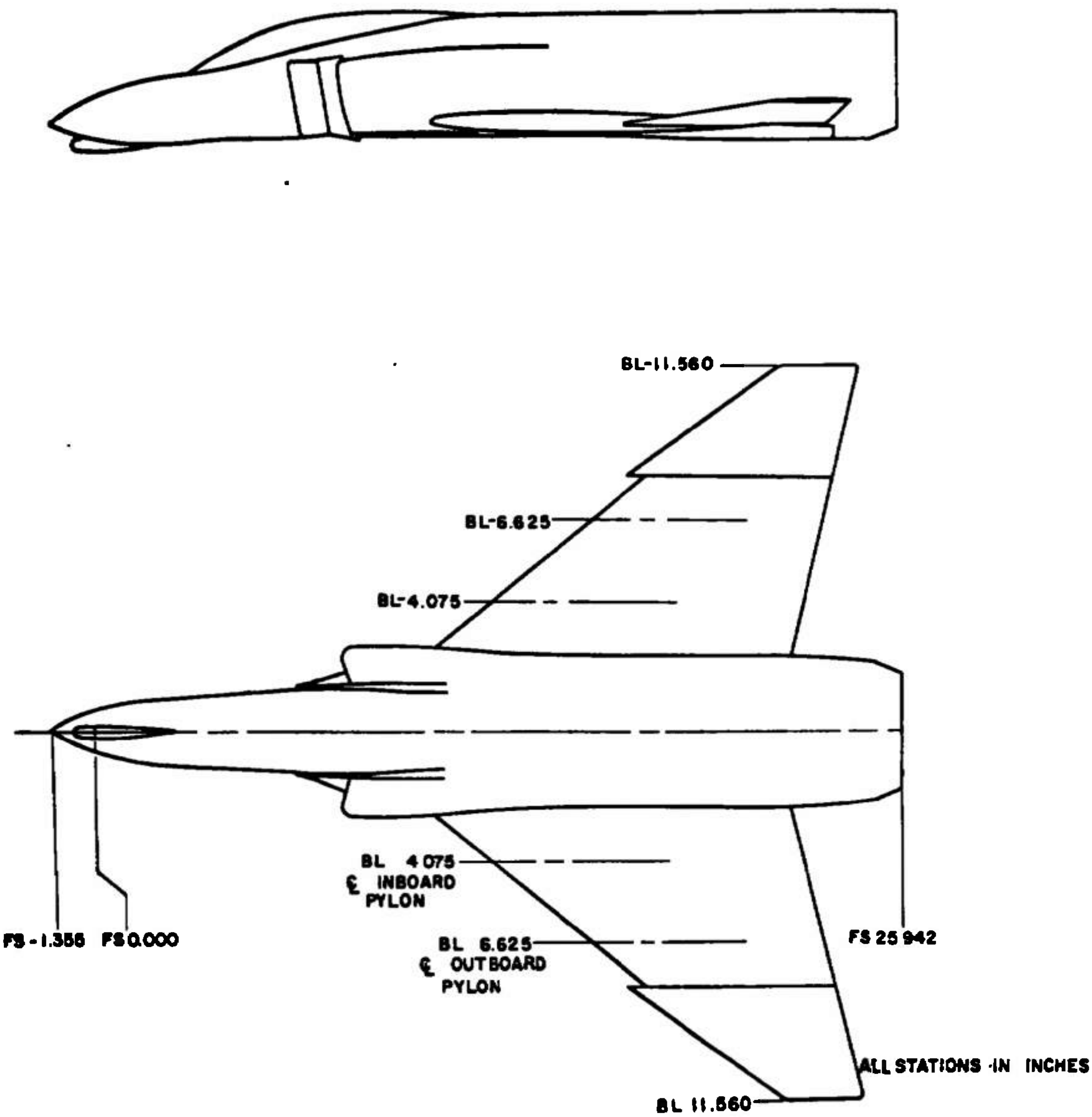


Fig. 3 Details and Basic Dimensions of the F-4C Parent Aircraft Model

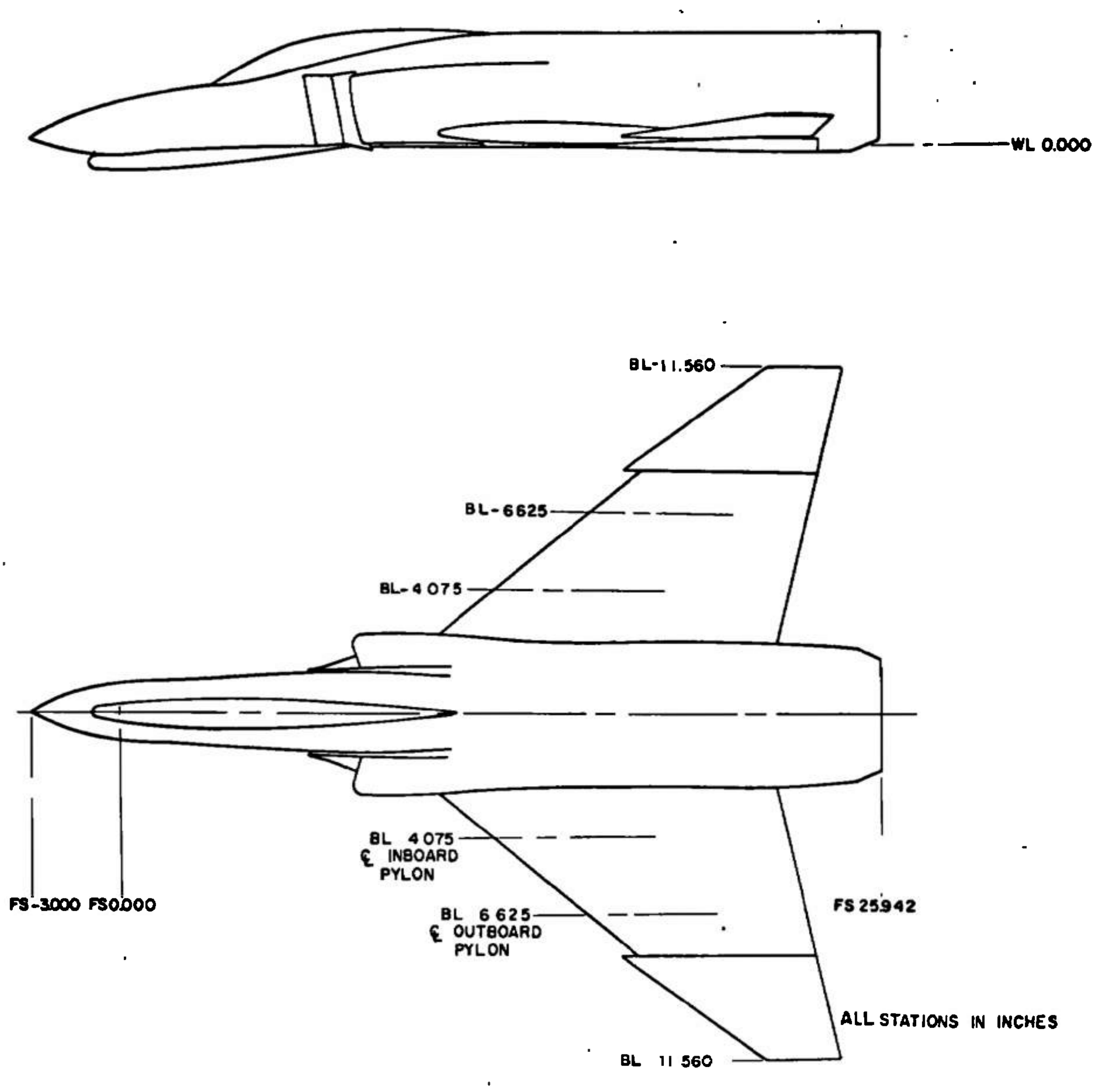


Fig. 4 Details and Basic Dimensions of the F-4E Parent Aircraft Model

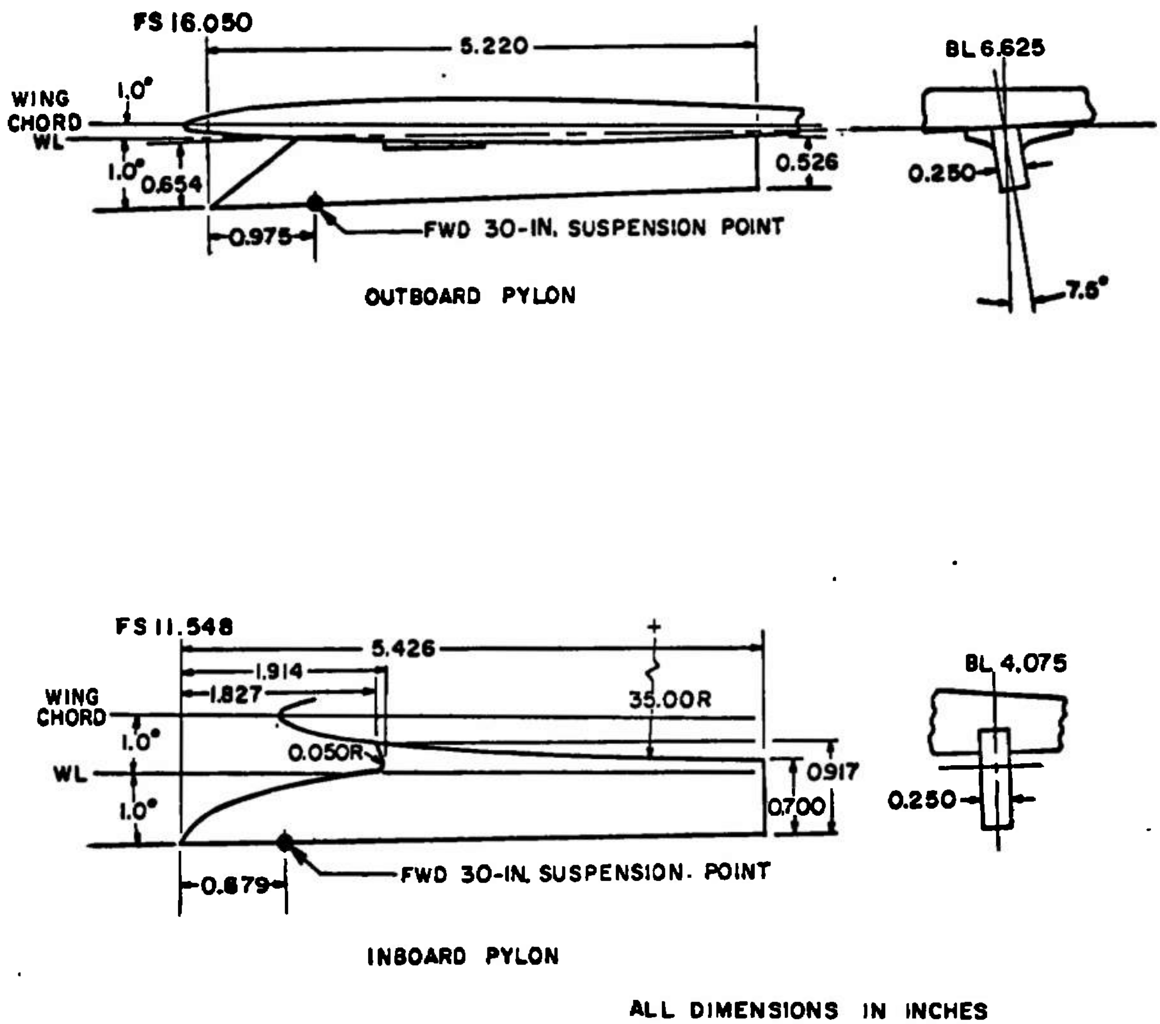
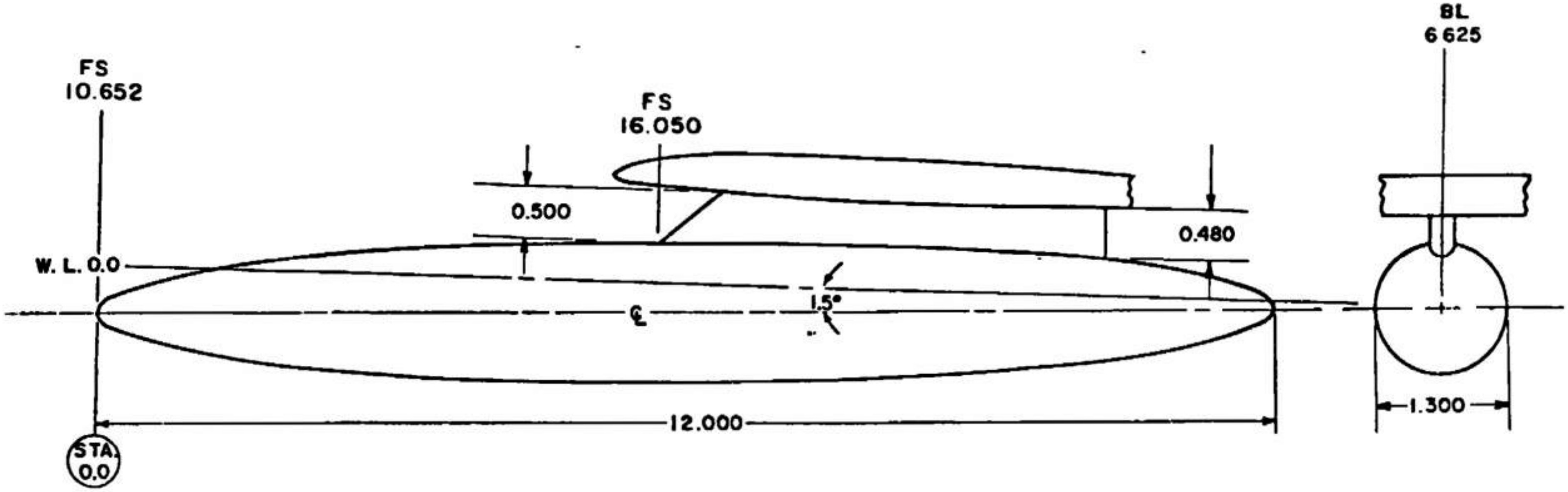


Fig. 5 Dimensional Sketch of the Outboard and Inboard Pylons



ALL MODEL STATIONS AND DIMENSIONS IN INCHES

BODY CONTOUR, TYPICAL BOTH ENDS

STATION	BODY DIAM	STATION	BODY DIAM
0 000	0 000	2 500	1.116
0 025	0 100	2.750	1 156
0.050	0 144	3 000	1 190
0 150	0.258	3 250	1 218
0 250	0.340	3 500	1.242
0 500	0 498	3 750	1 260
0 750	0 622	4 000	1 274
1 000	0 724	4 250	1 286
1 250	0 812	4 500	1 294
1 500	0 890	4 750	1 298
1 750	0 958	5 000	1 300
2 000	1 016	6 000	1 300
2 250	1 070		

Fig. 6 Dimensional Sketch of the 370-gal Fuel Tank and Outboard Pylon

BODY CONTOUR

Y	R	Y	R
0.000	0.000	7.000	0.852
0.050	0.049	7.250	0.846
0.100	0.077	7.500	0.839
0.150	0.101	7.750	0.830
0.200	0.122	8.000	0.820
0.250	0.143	8.250	0.809
0.500	0.232	8.500	0.796
0.750	0.308	8.750	0.781
1.000	0.376	9.000	0.765
1.250	0.438	9.250	0.745
1.500	0.494	9.500	0.722
1.750	0.546	9.750	0.695
2.000	0.593	10.000	0.664
2.250	0.637	10.250	0.629
2.500	0.679	10500	0.591
2.750	0.713	10.750	0.550
3.000	0.740	11.000	0.506
3.250	0.762	11.250	0.461
3.500	0.782	11.500	0.413
3.750	0.799	11.750	0.362
4.000	0.814	12.000	0.307
4.250	0.827	12.250	0.248
4.500	0.838	12.500	0.183
4.750	0.847	12.750	0.110
5.000	0.854	12800	0.094
5.250	0.859	12850	0.078
5.500	0.860	12.900	0.061
6.250	0.860	12.950	0.044
6.500	0.859	12.975	0.035
6.750	0.856	13000	0.000

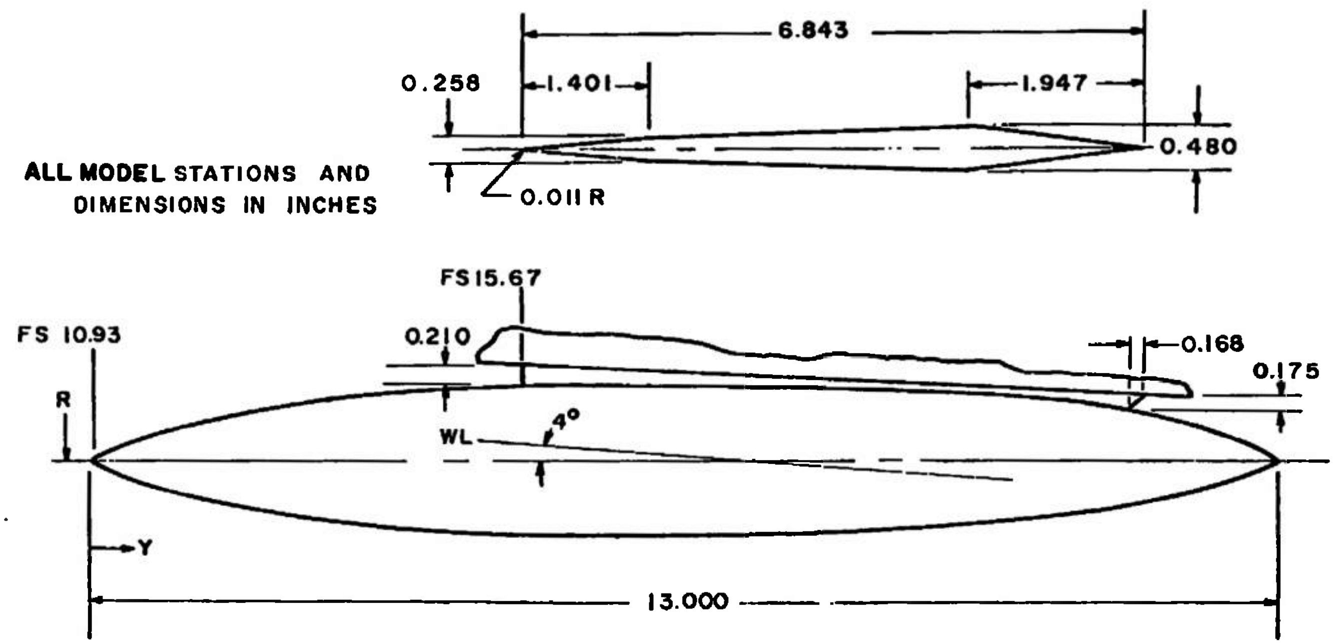
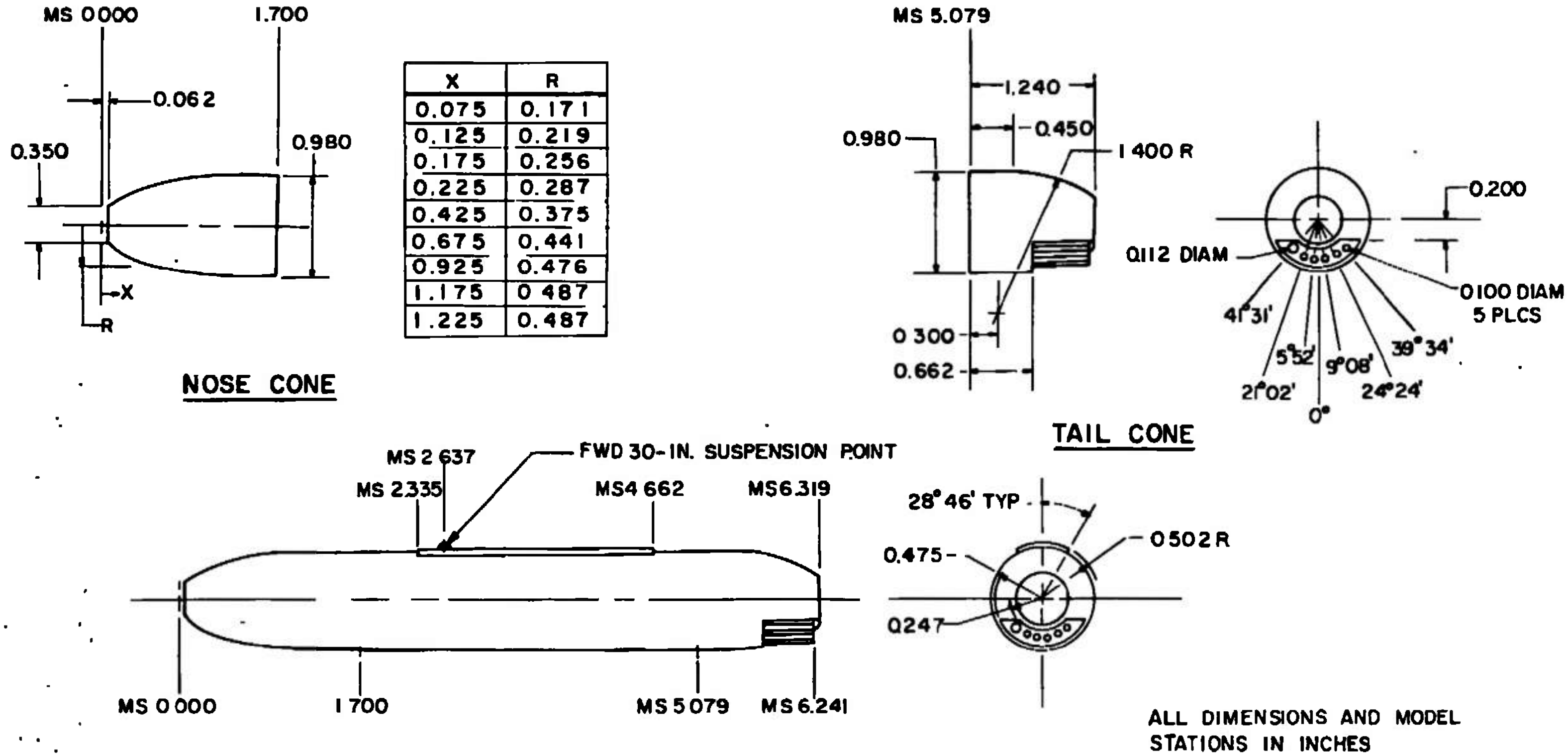


Fig. 7 Dimensional Sketch of the 600-gal Fuel Tank and Centerline Pylon



X	R
0.075	0.171
0.125	0.219
0.175	0.256
0.225	0.287
0.425	0.375
0.675	0.441
0.925	0.476
1.175	0.487
1.225	0.487

Fig. 8 Dimensional Sketch of the ALE-38 Chaff Dispenser

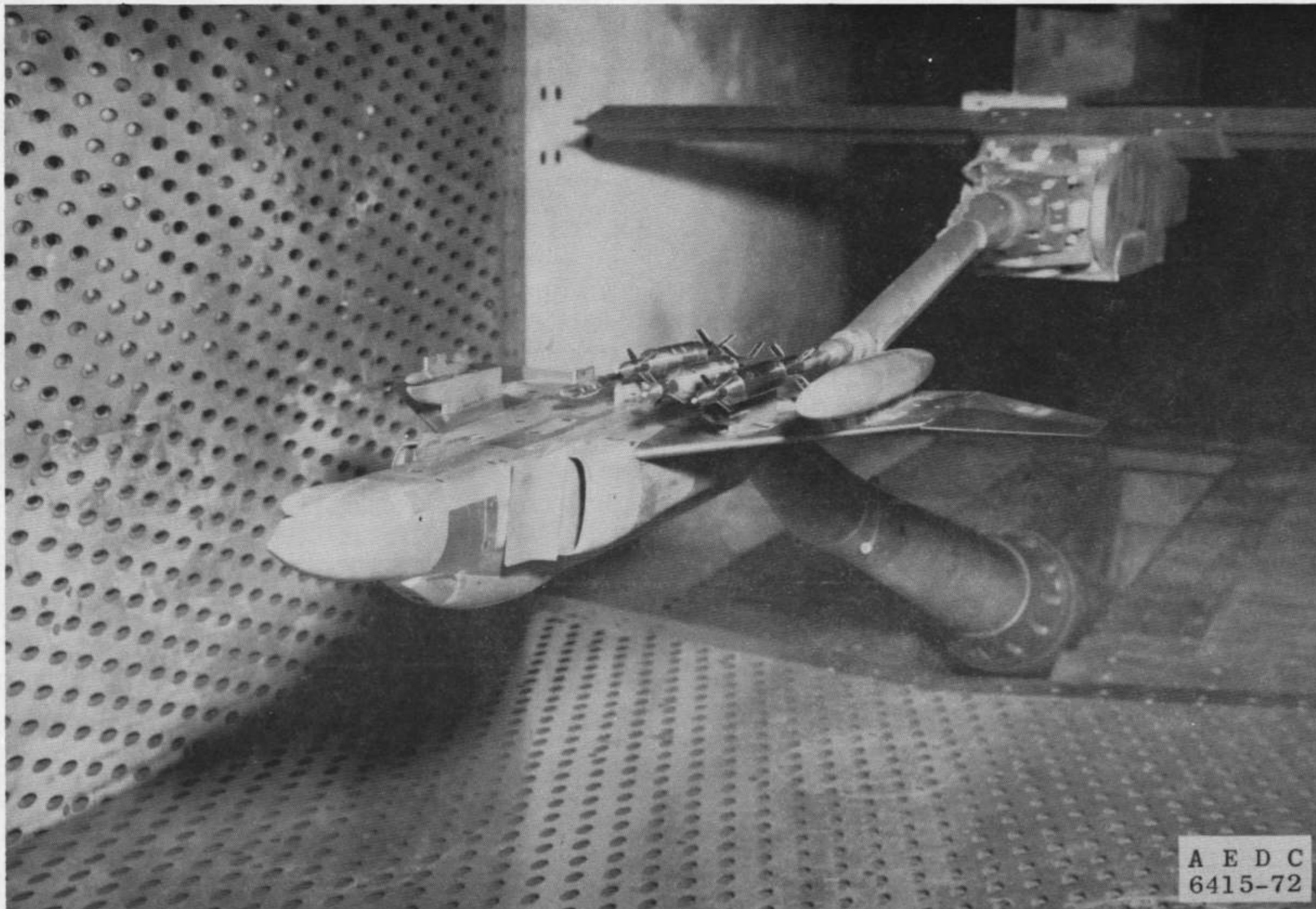


Fig. 9 Photograph of a Typical Test Installation

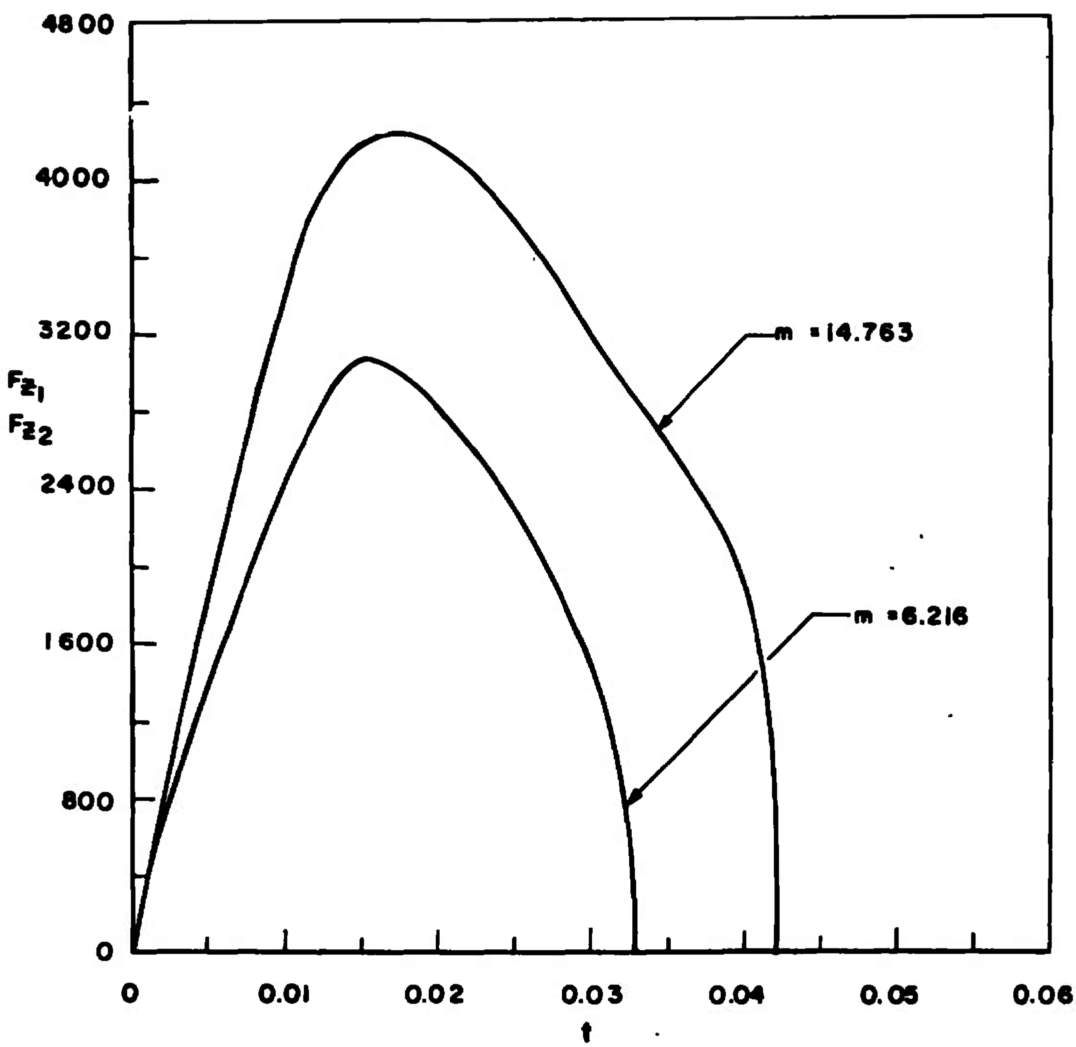
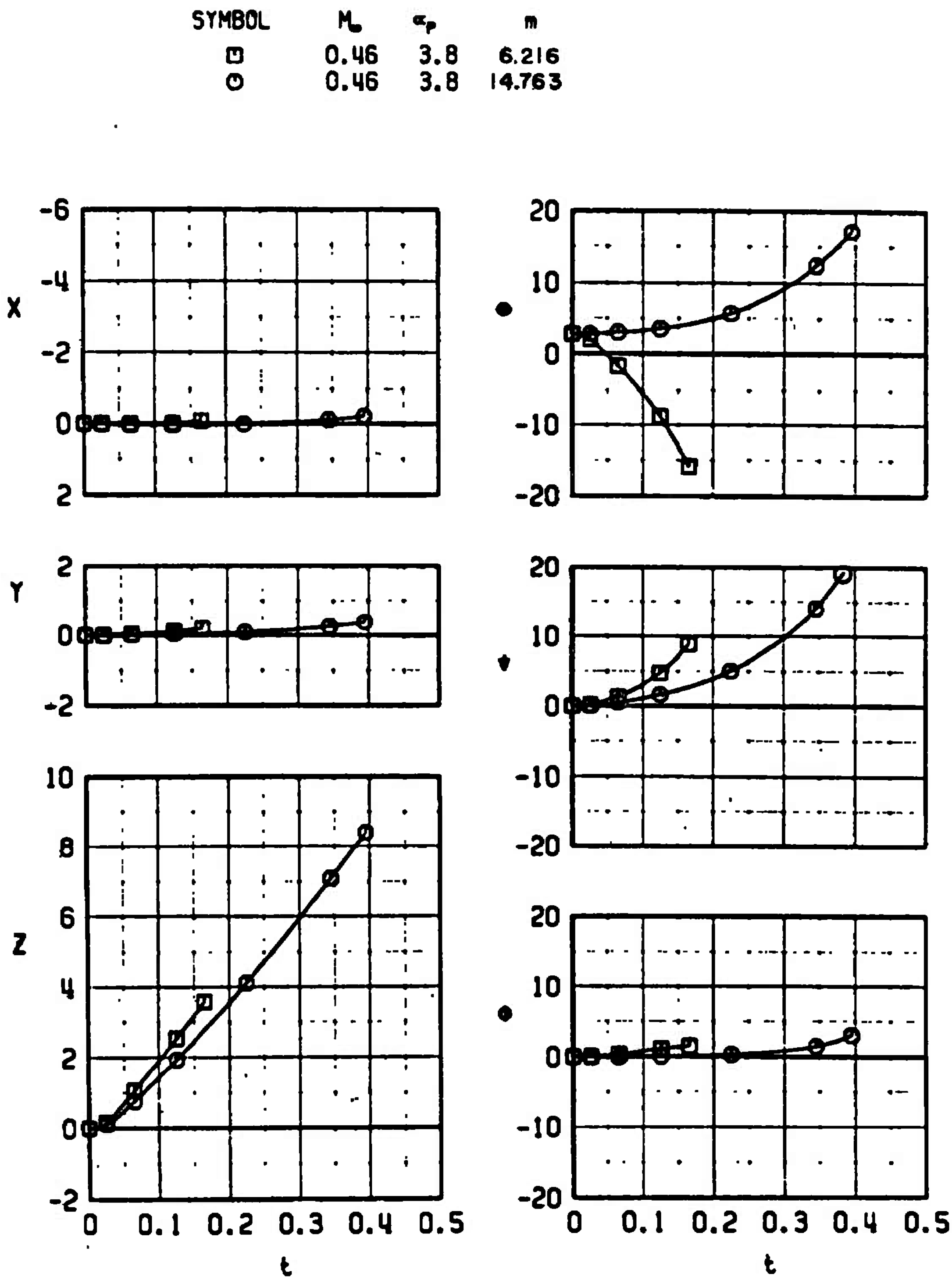
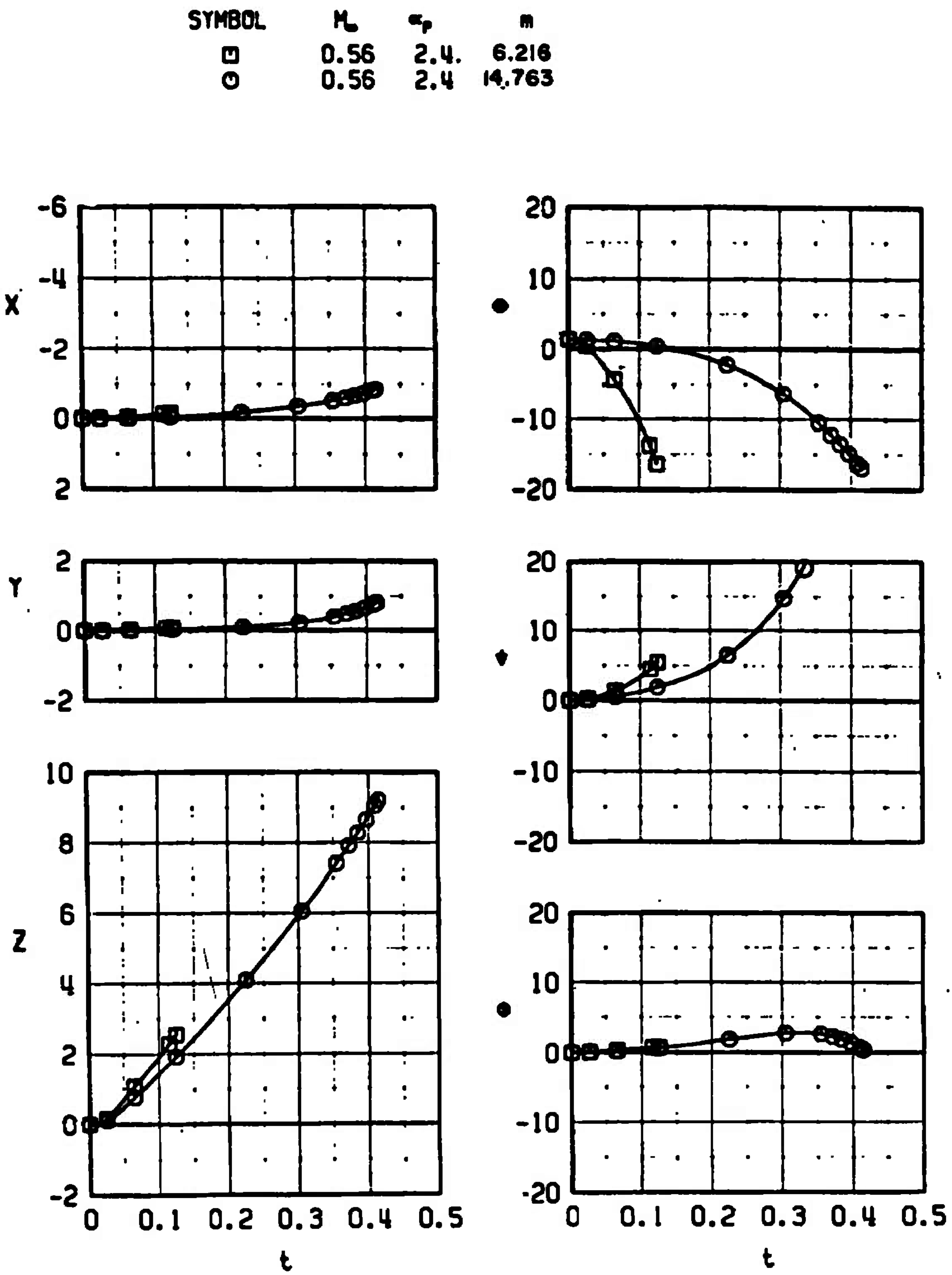


Fig. 10 Simulated Ejector Force as a Function of Time

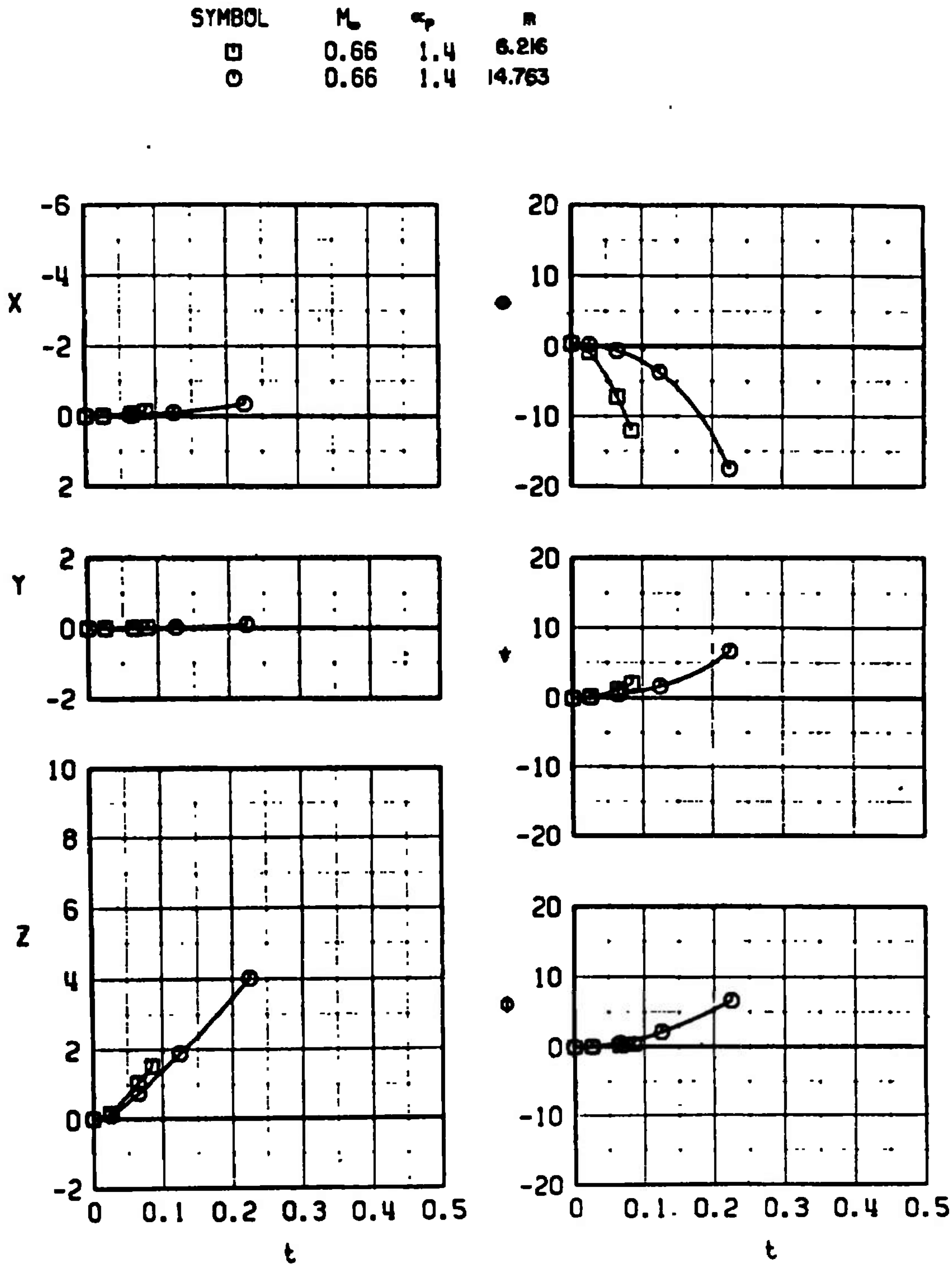


a. $M_\infty = 0.46$

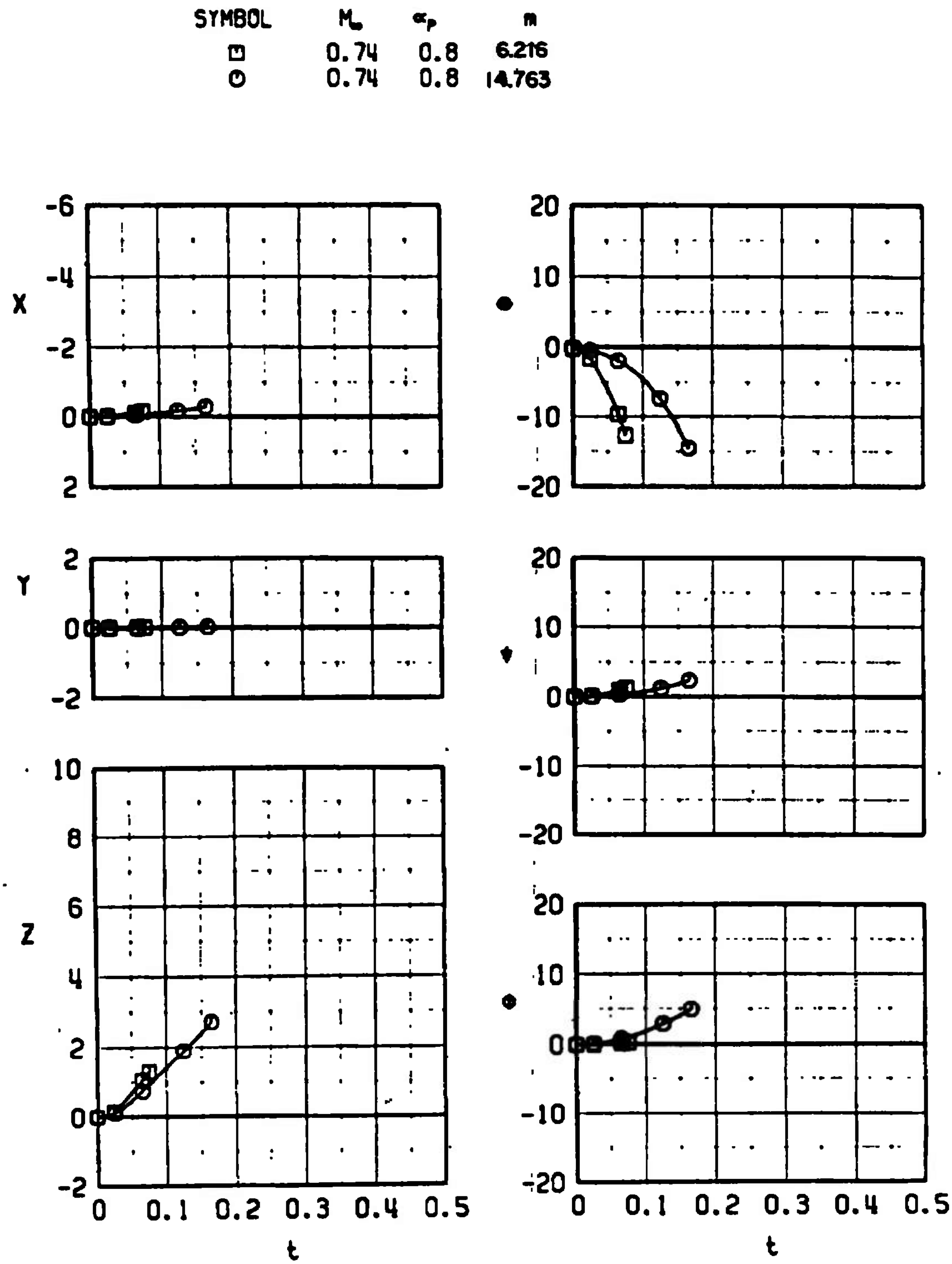
Fig. 11 Effect of Store Weight on the Trajectory of the ALE-38 Chaff Dispenser when Ejected from the F-4C Aircraft, Configuration 1



b. $M_\infty = 0.56$
Fig. 11 Continued

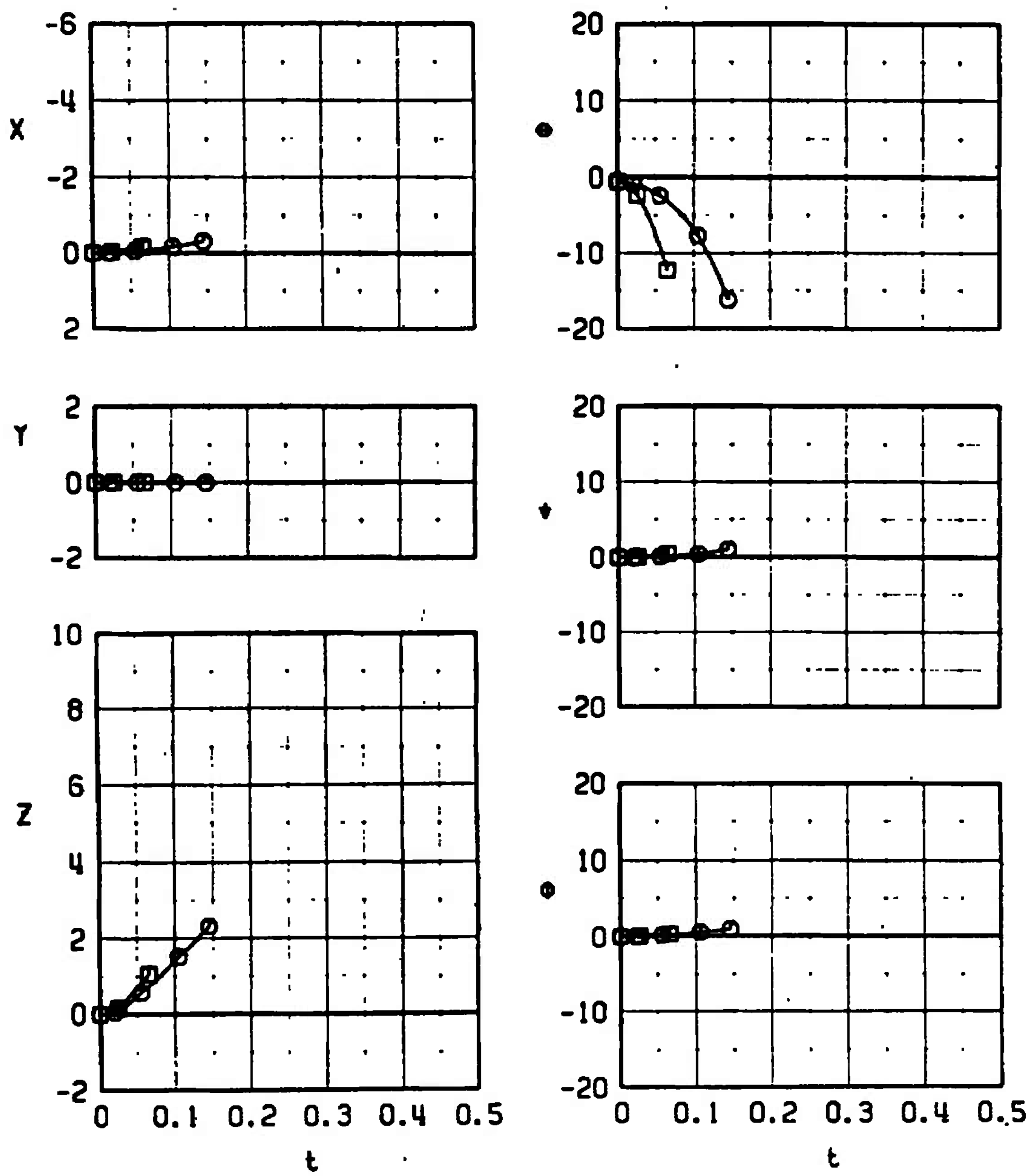


c. $M_\infty = 0.66$
Fig. 11 Continued



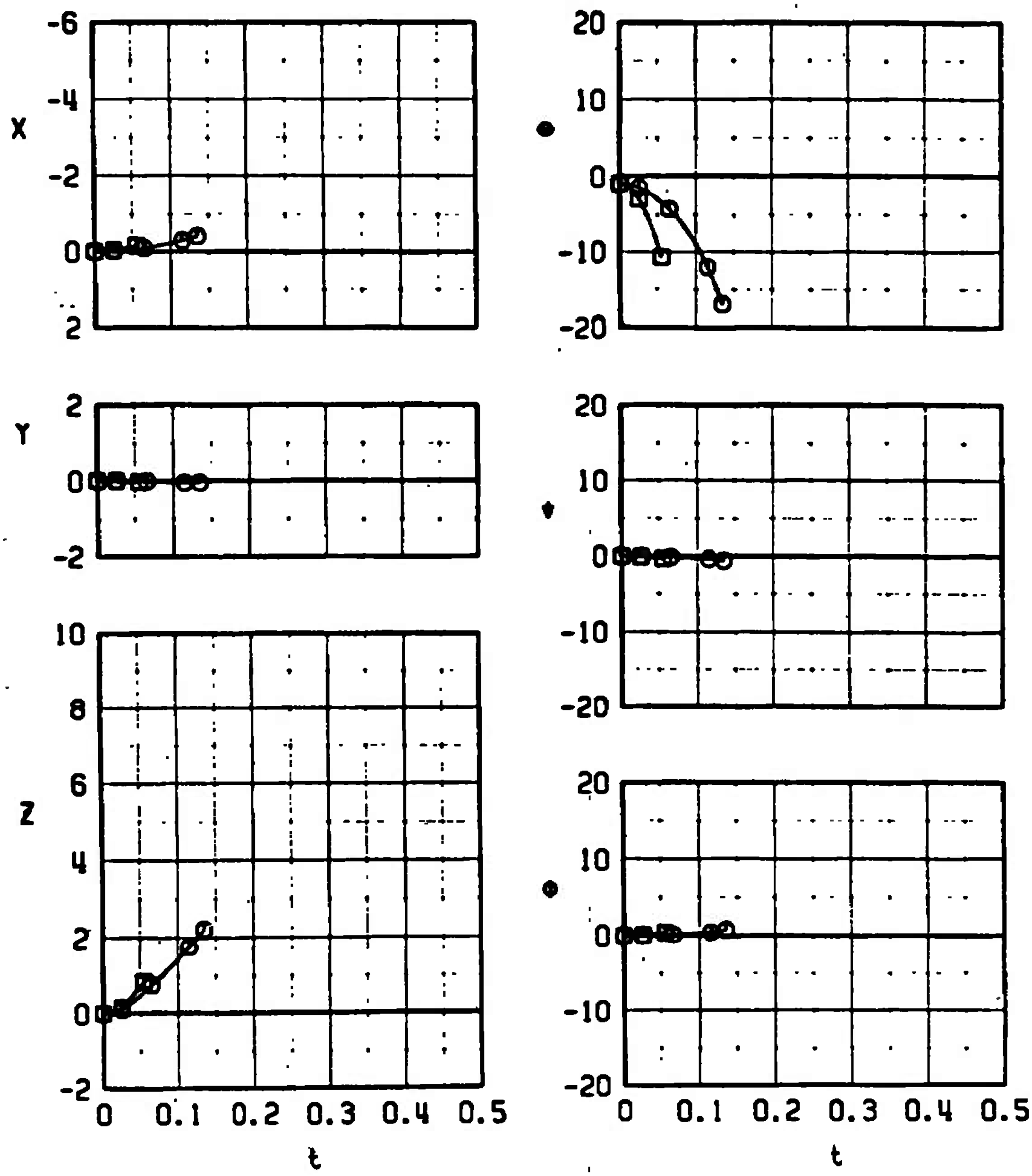
d. M_∞ = 0.74
Fig. 11 Continued

SYMBOL	M_∞	α_p	m
□	0.82	0.4	6.216
○	0.82	0.4	14.763



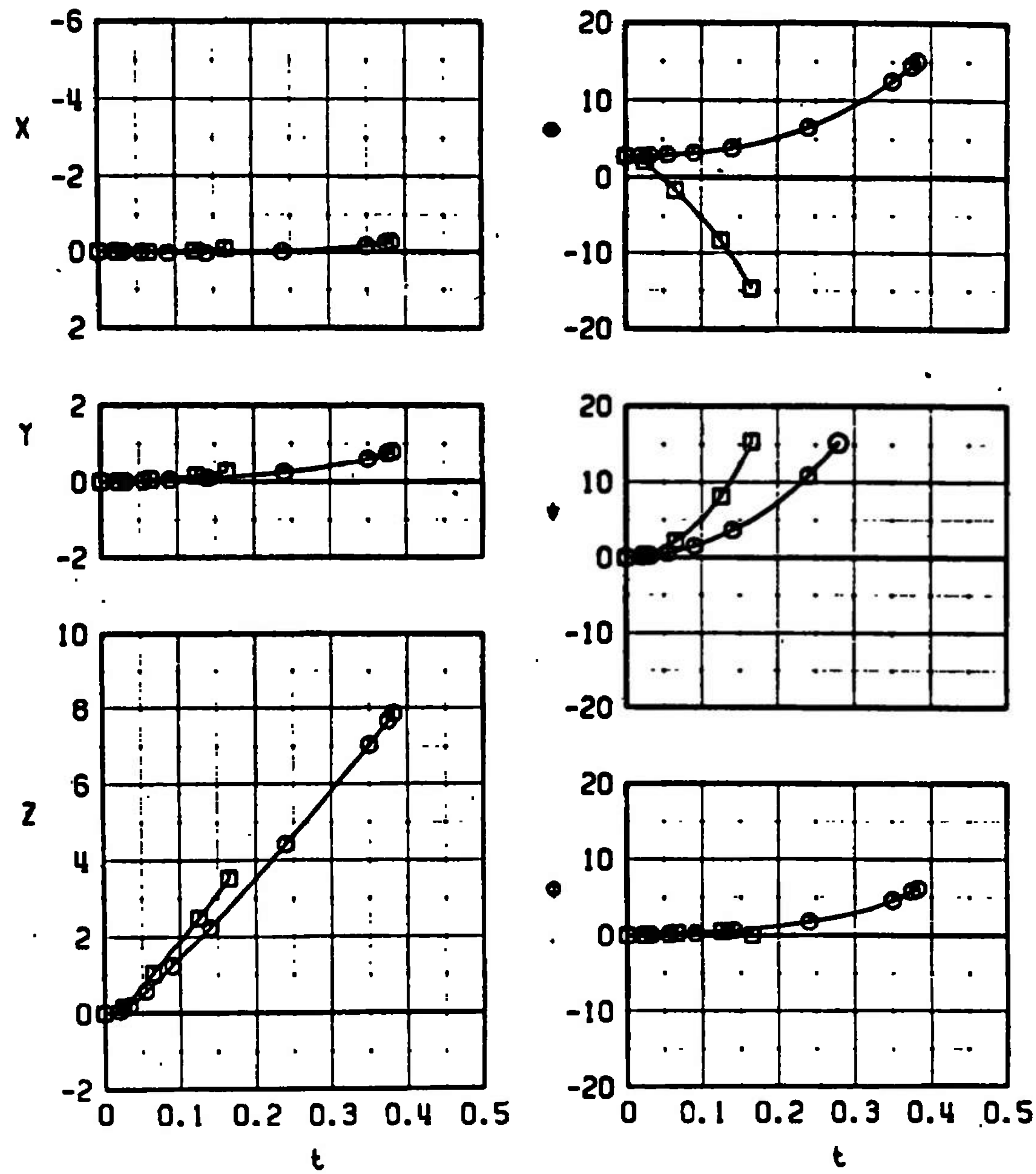
e. M_∞ = 0.82
Fig. 11 Continued

SYMBOL	M_∞	α_p	m
□	0.90	0.0	6.216
○	0.90	0.0	14.763



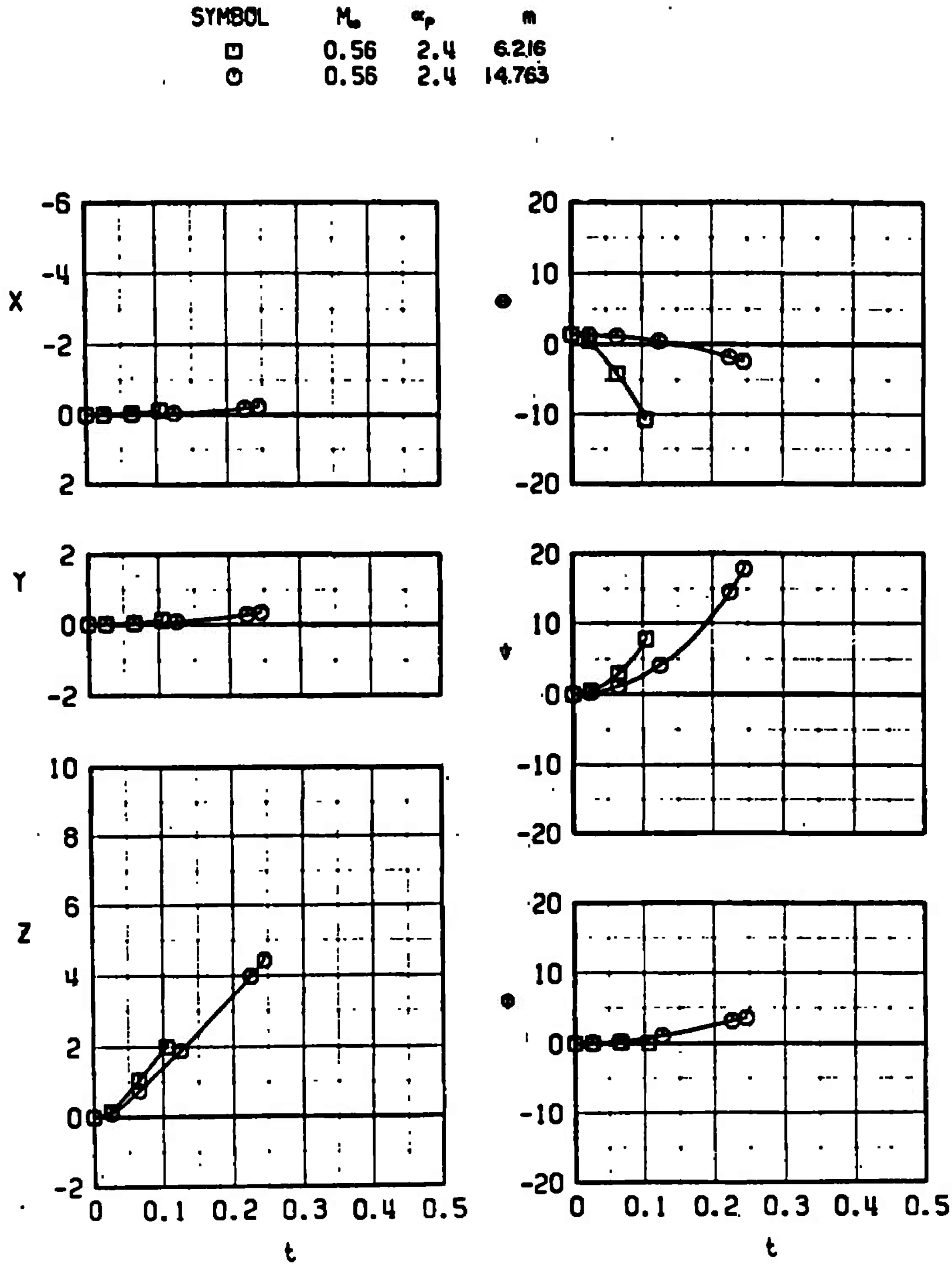
f. $M_\infty = 0.90$
Fig. 11 Concluded

SYMBOL	M_∞	α_p	m
□	0.46	3.8	6.216
○	0.46	3.8	14.763

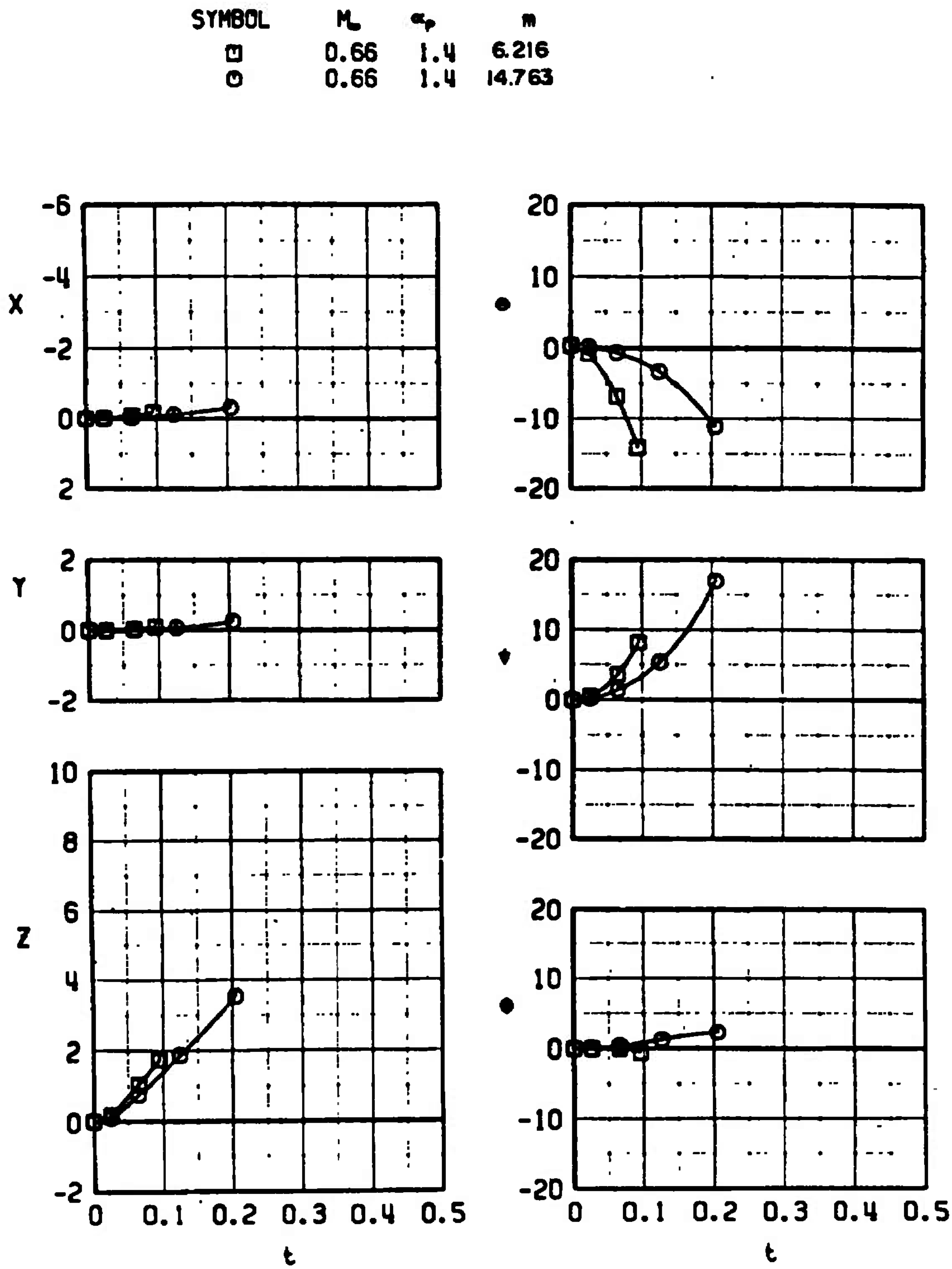


a. $M_\infty = 0.46$

Fig. 12 Effect of Store Weight on the Trajectory of the ALE-38 Chaff Dispenser when Ejected from the F-4C Aircraft, Configuration 2

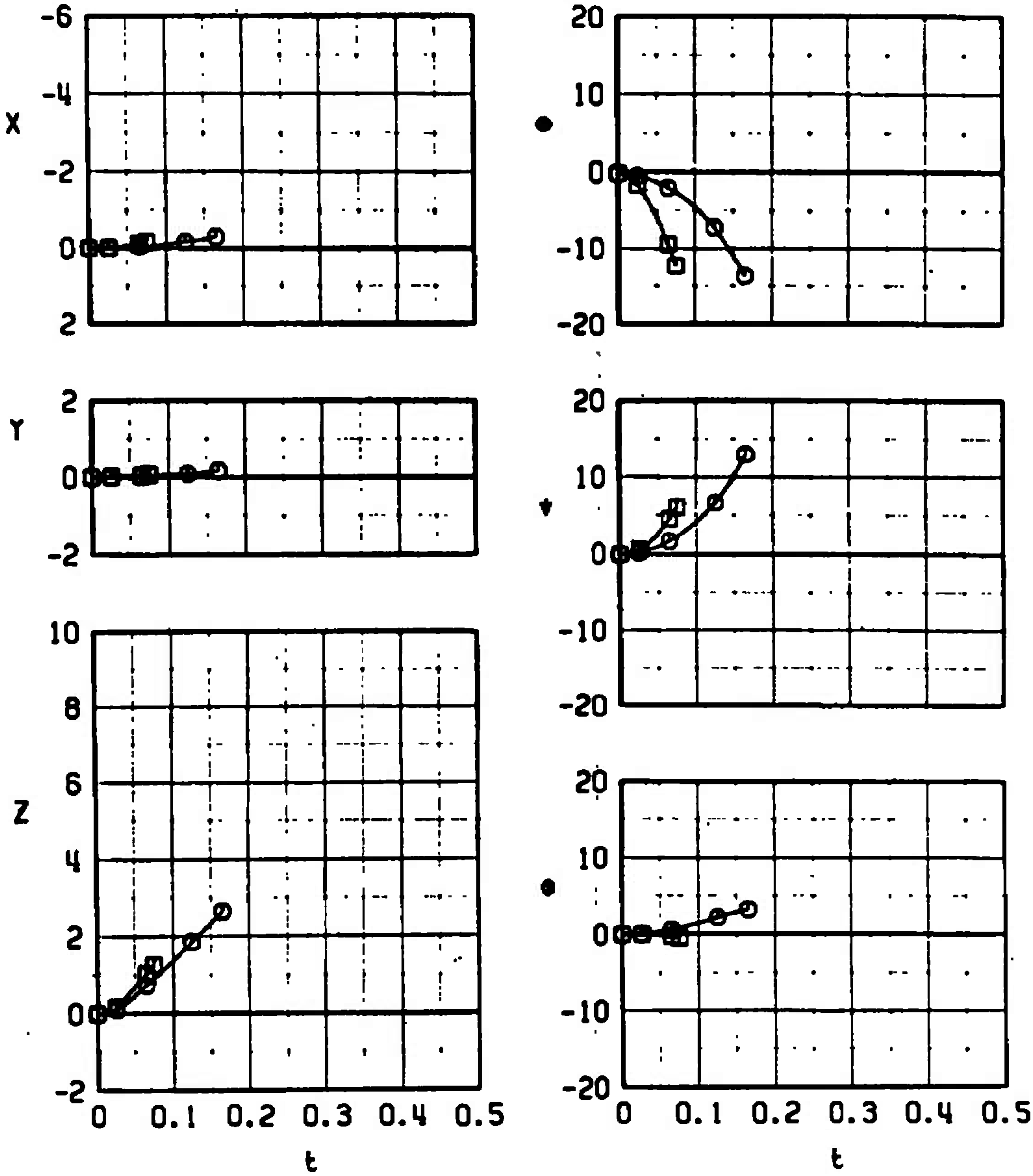


b. $M_\infty = 0.56$
Fig. 12 Continued

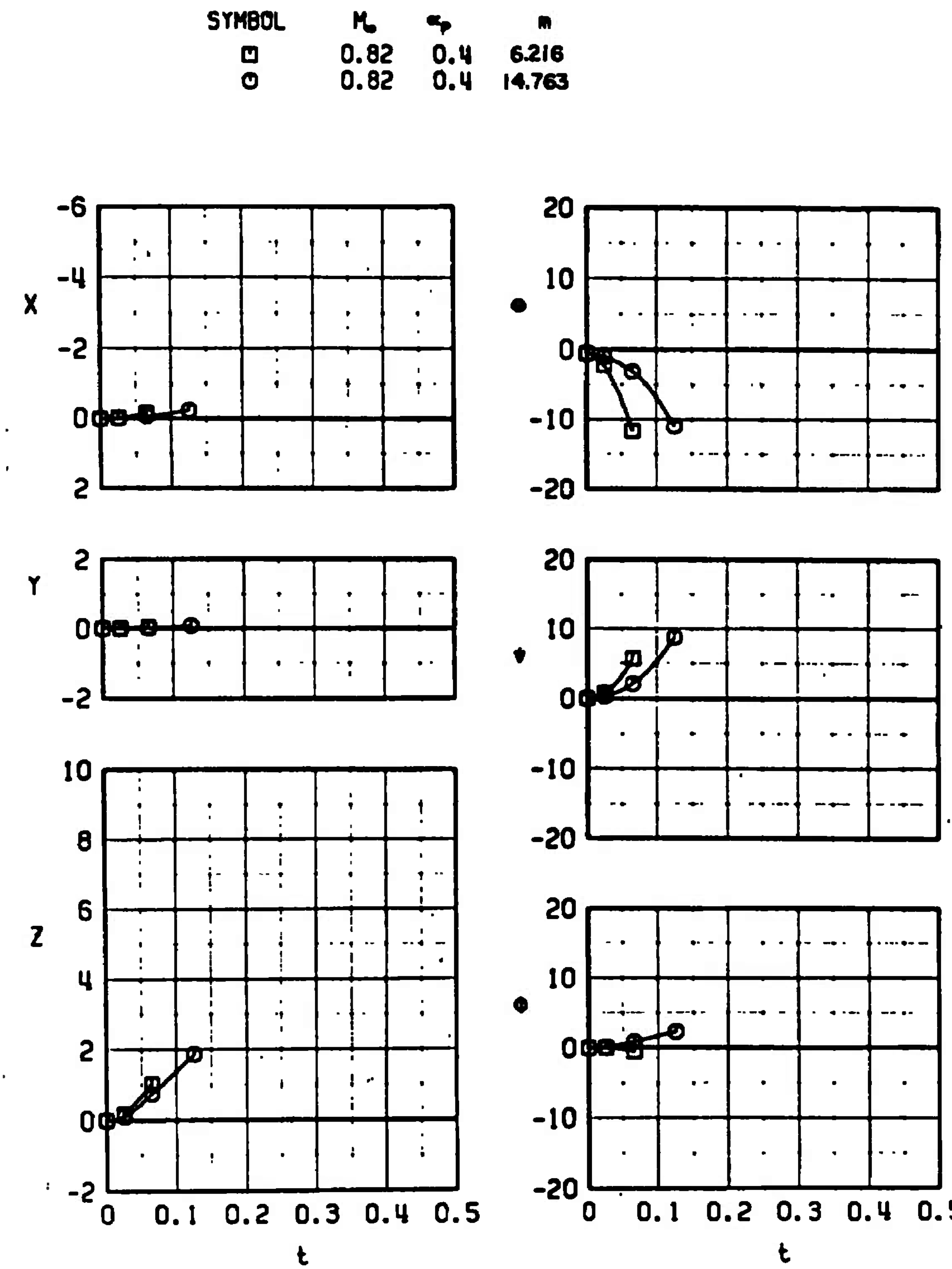


c. $M_\infty = 0.66$
Fig. 12 Continued

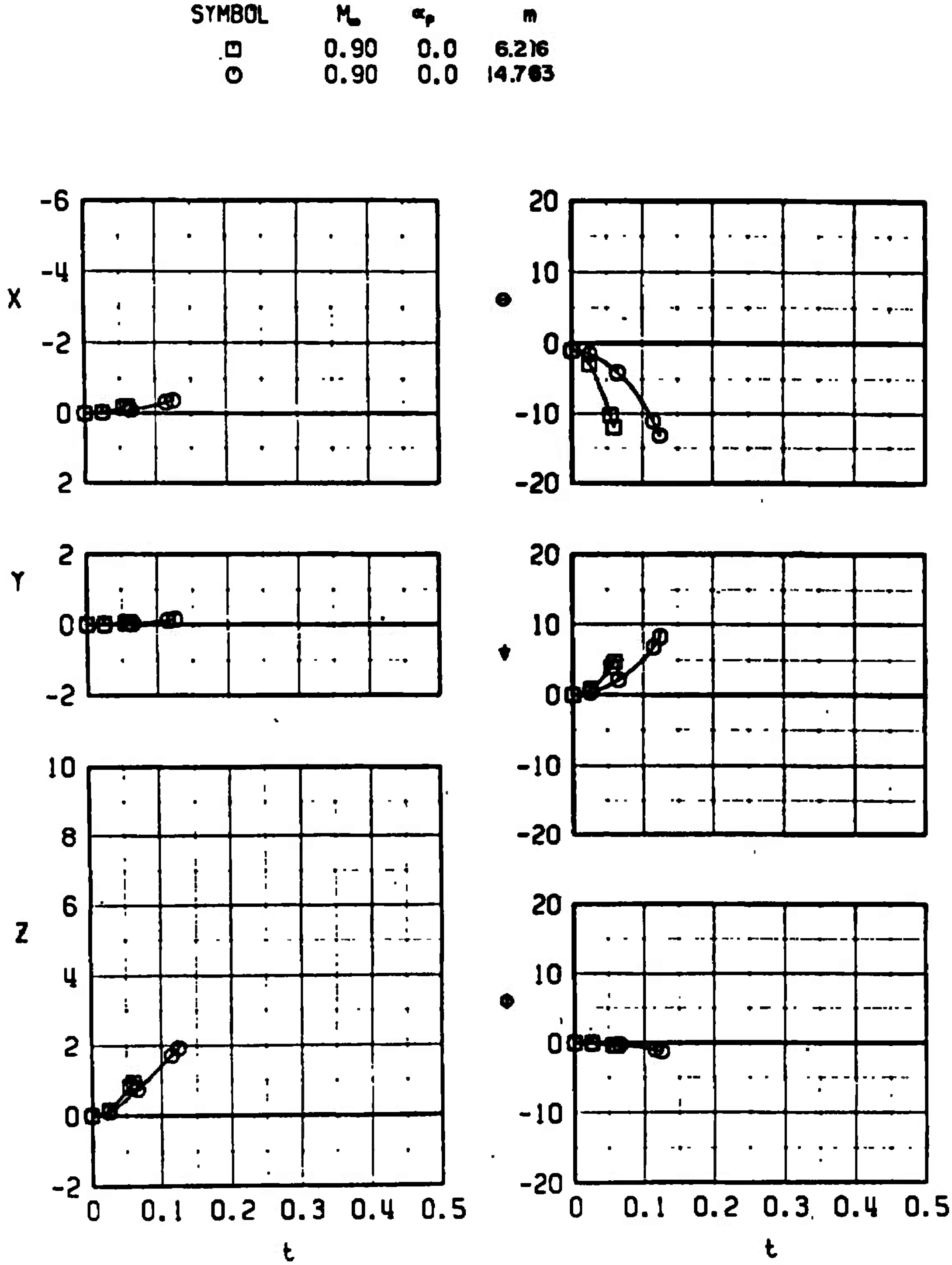
SYMBOL	M_∞	α_p	m
□	0.74	0.8	6.216
○	0.74	0.8	14.763



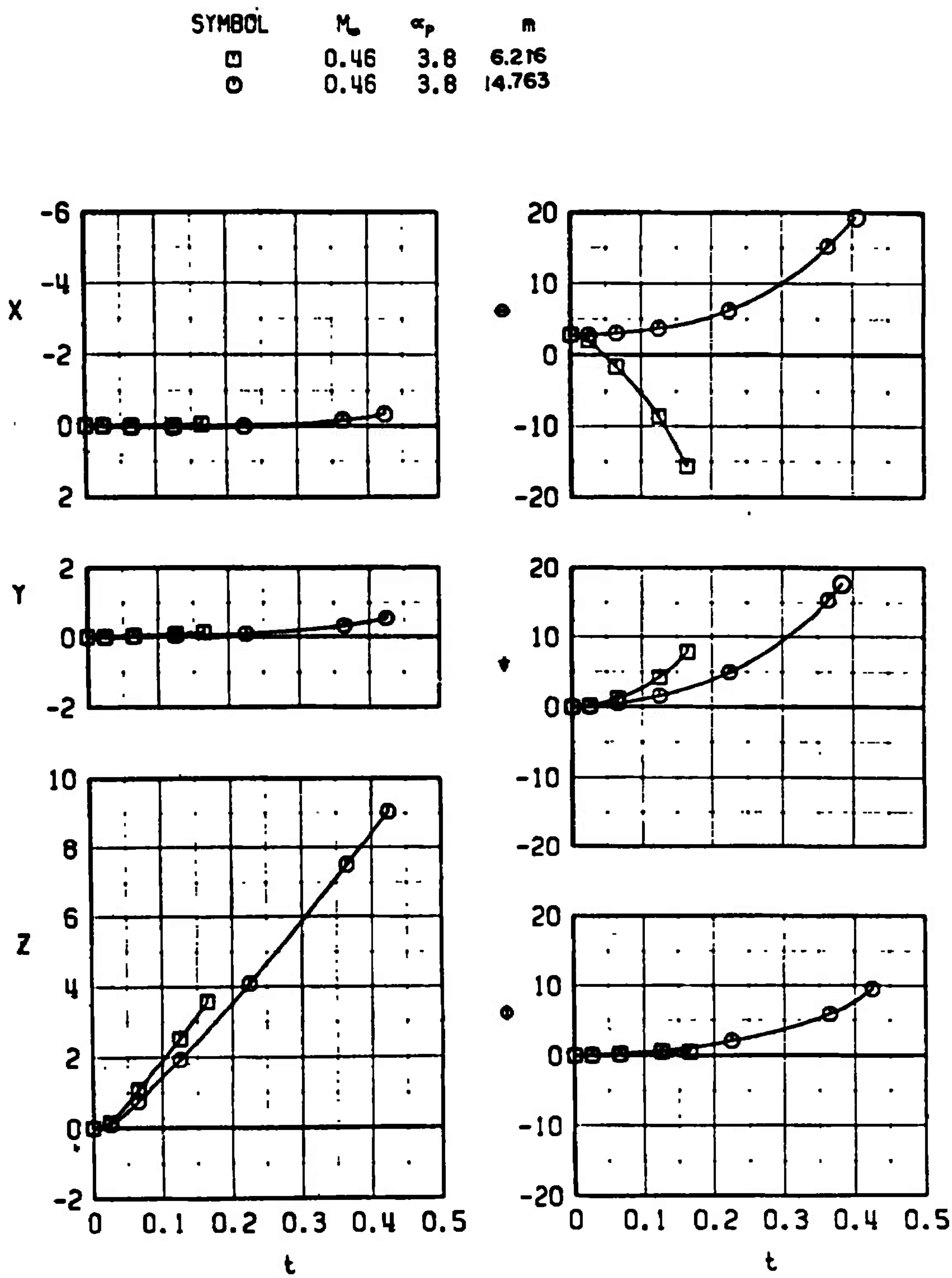
d. $M_\infty = 0.74$
Fig. 12 Continued



e. $M_\infty = 0.82$
Fig. 12 Continued

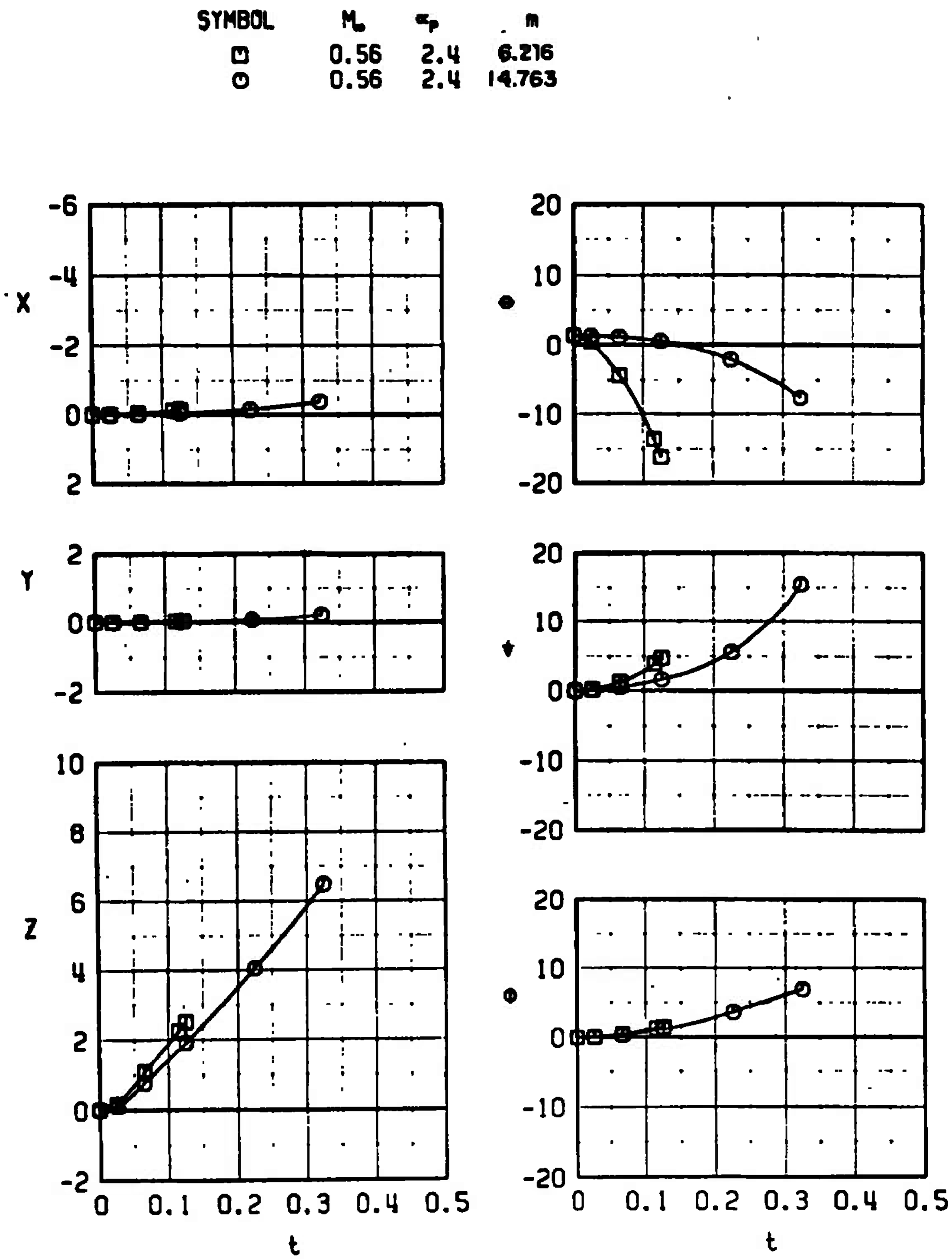


f. $M_\infty = 0.90$
Fig. 12 Concluded

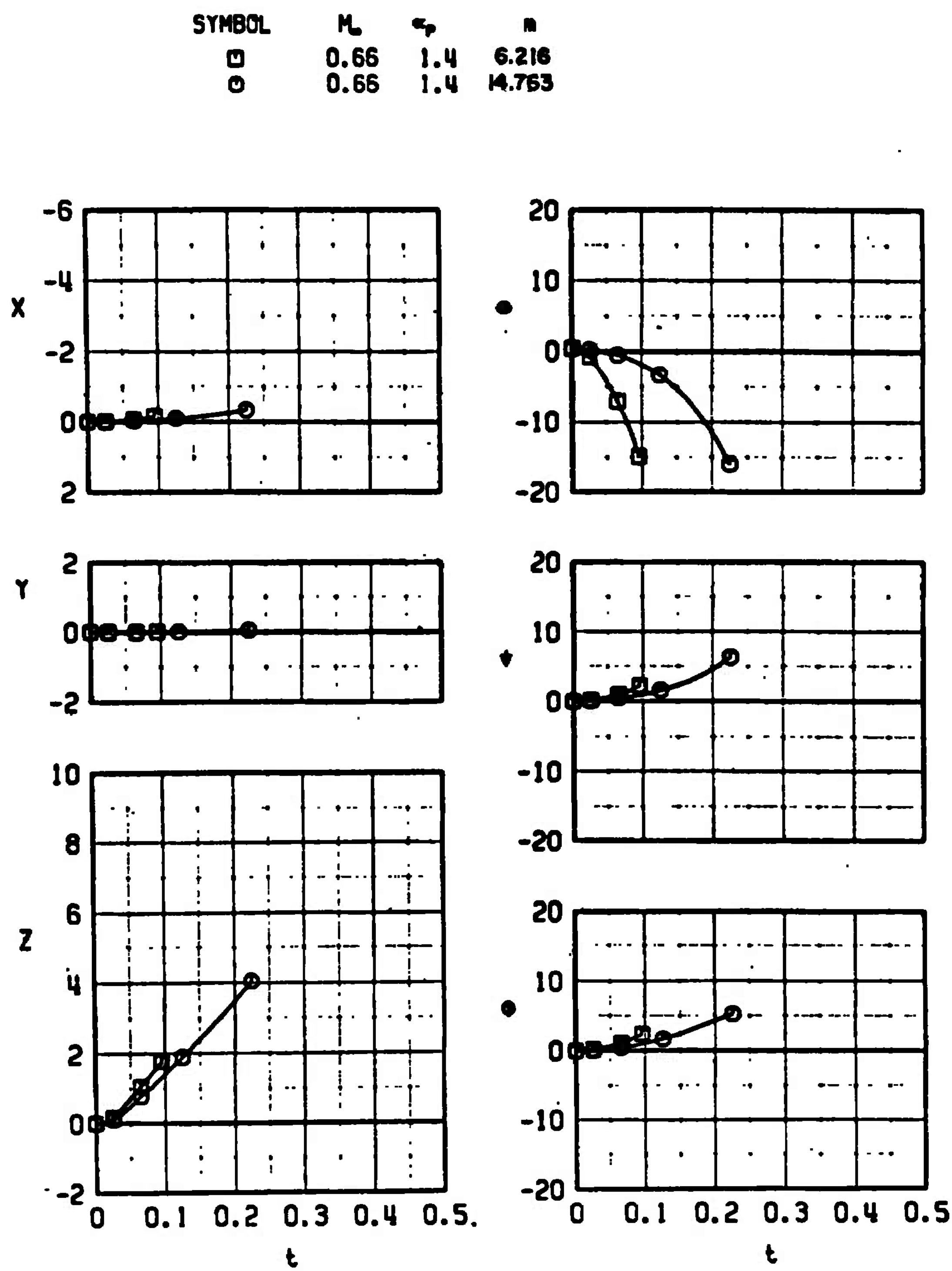


a. $M_\infty = 0.46$

Fig. 13 Effect of Store Weight on the Trajectory of the ALE-38 Chaff Dispenser when Ejected from the F-4E Aircraft, Configuration 3

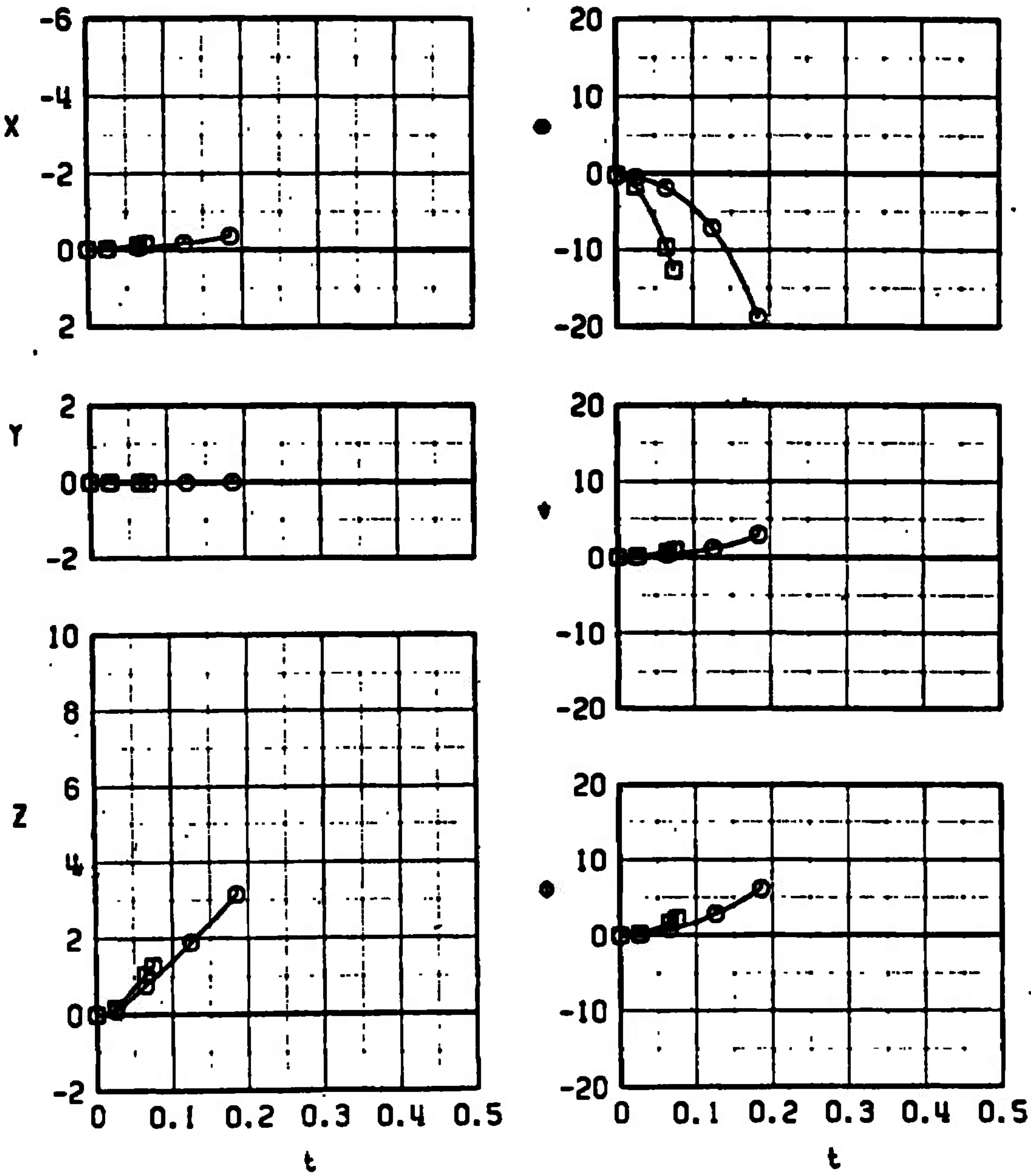


b. M_∞ = 0.56
Fig. 13 Continued

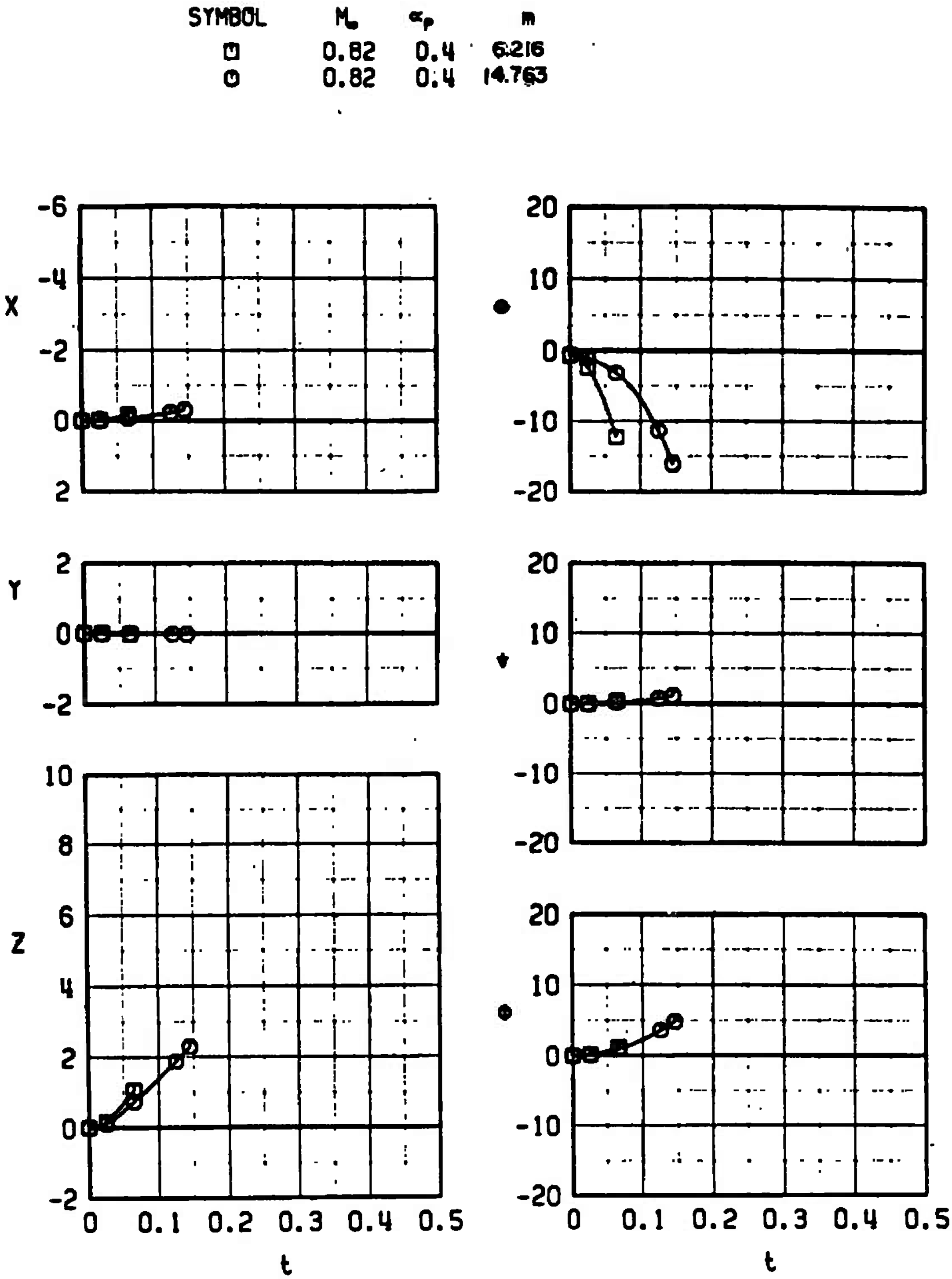


c. $M_\infty = 0.66$
Fig. 13 Continued

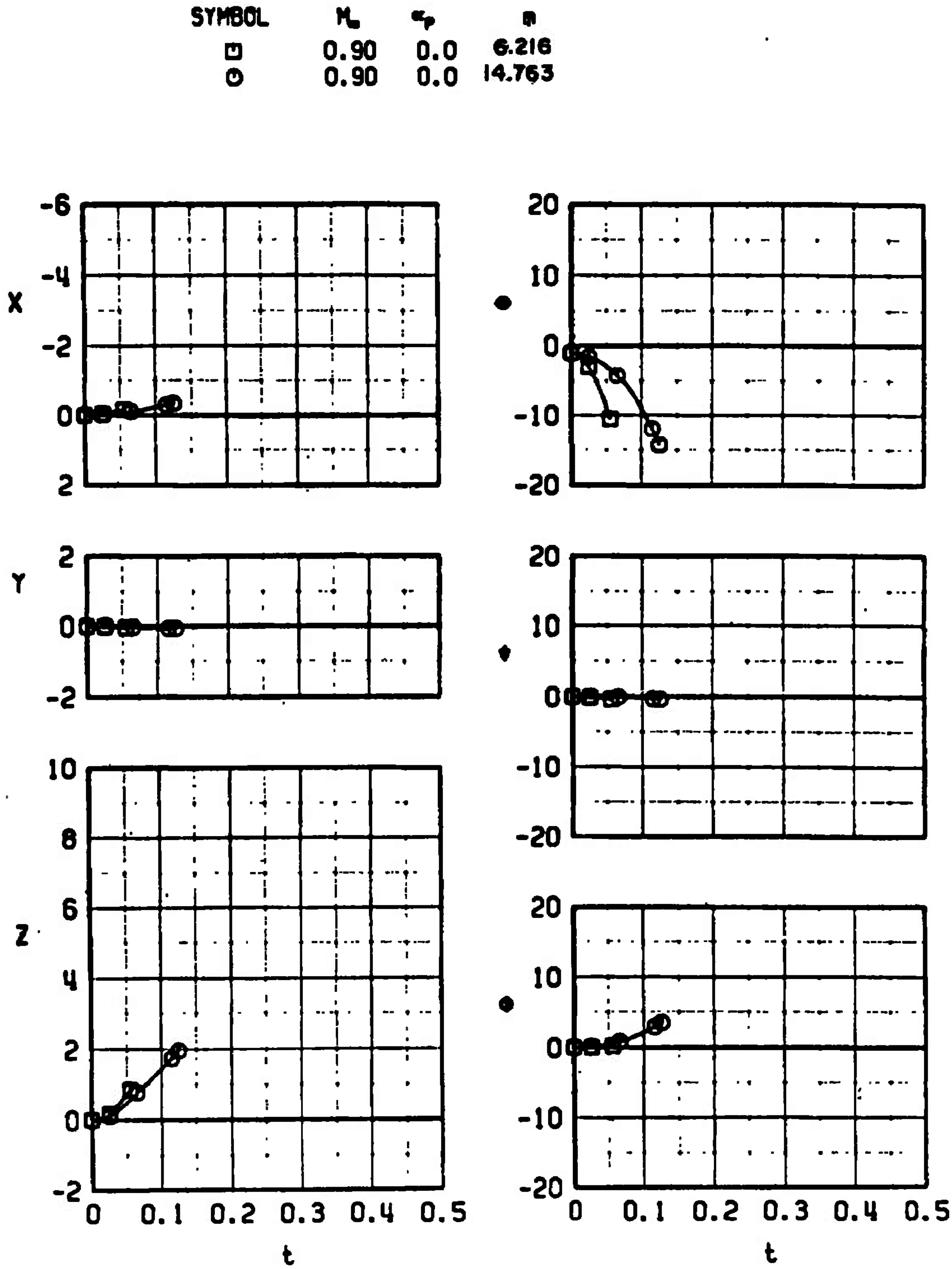
SYMBOL	M_∞	α_p	m
◻	0.74	0.8	6.216
○	0.74	0.8	14.763



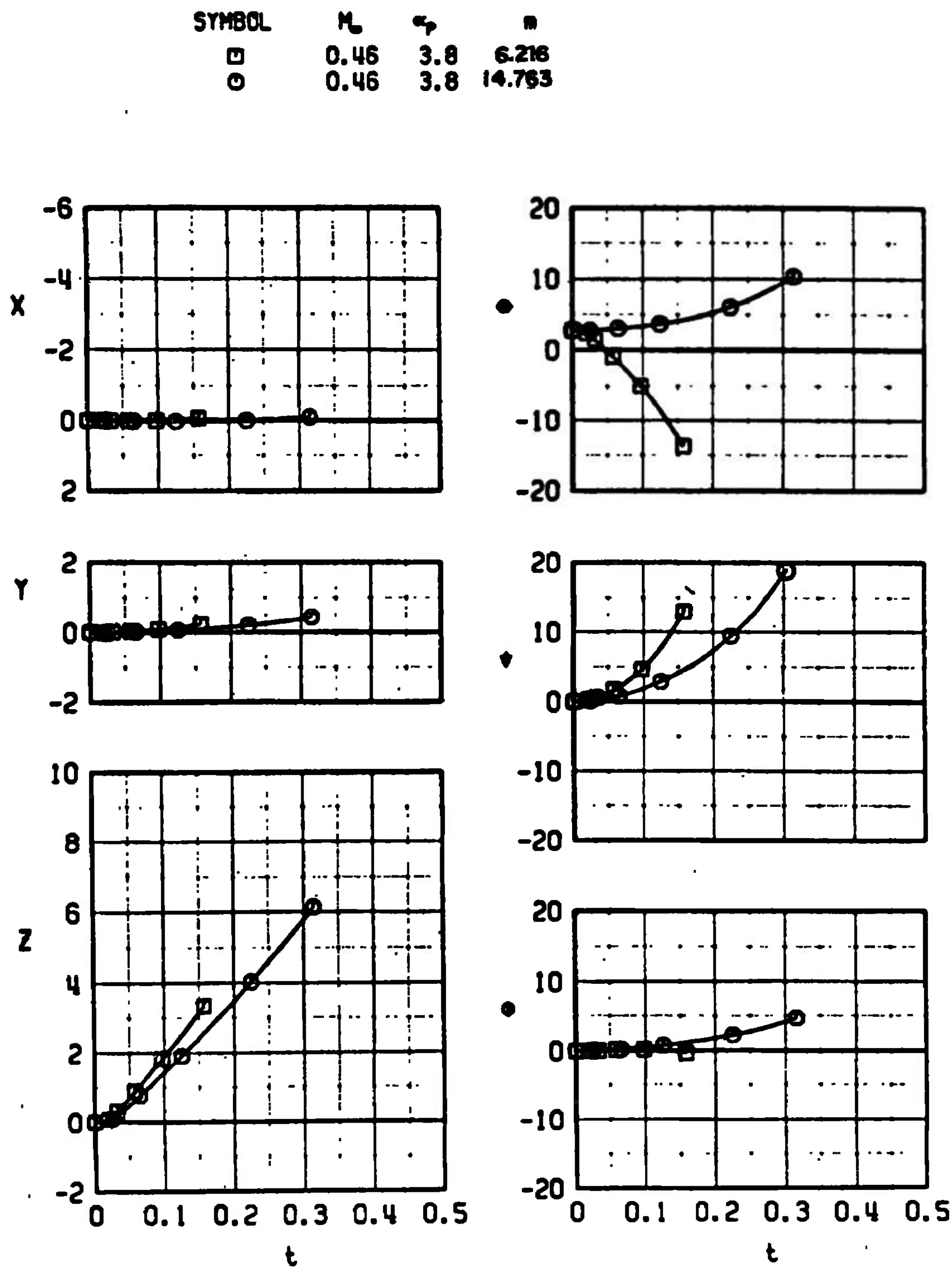
d. $M_\infty = 0.74$
Fig. 13 Continued



e. $M_\infty = 0.82$
Fig. 13 Continued

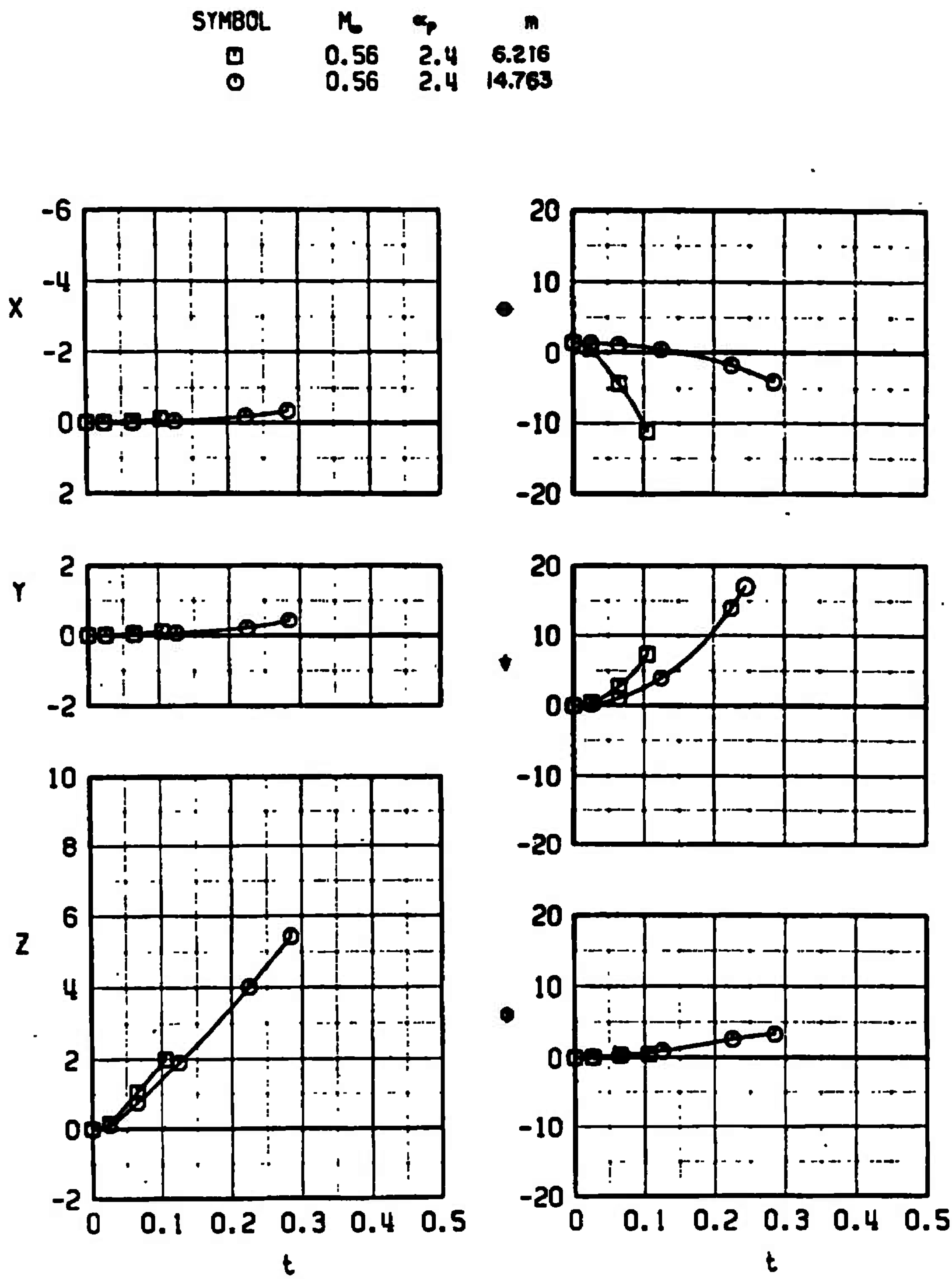


f. M_∞ = 0.90
Fig. 13 Concluded



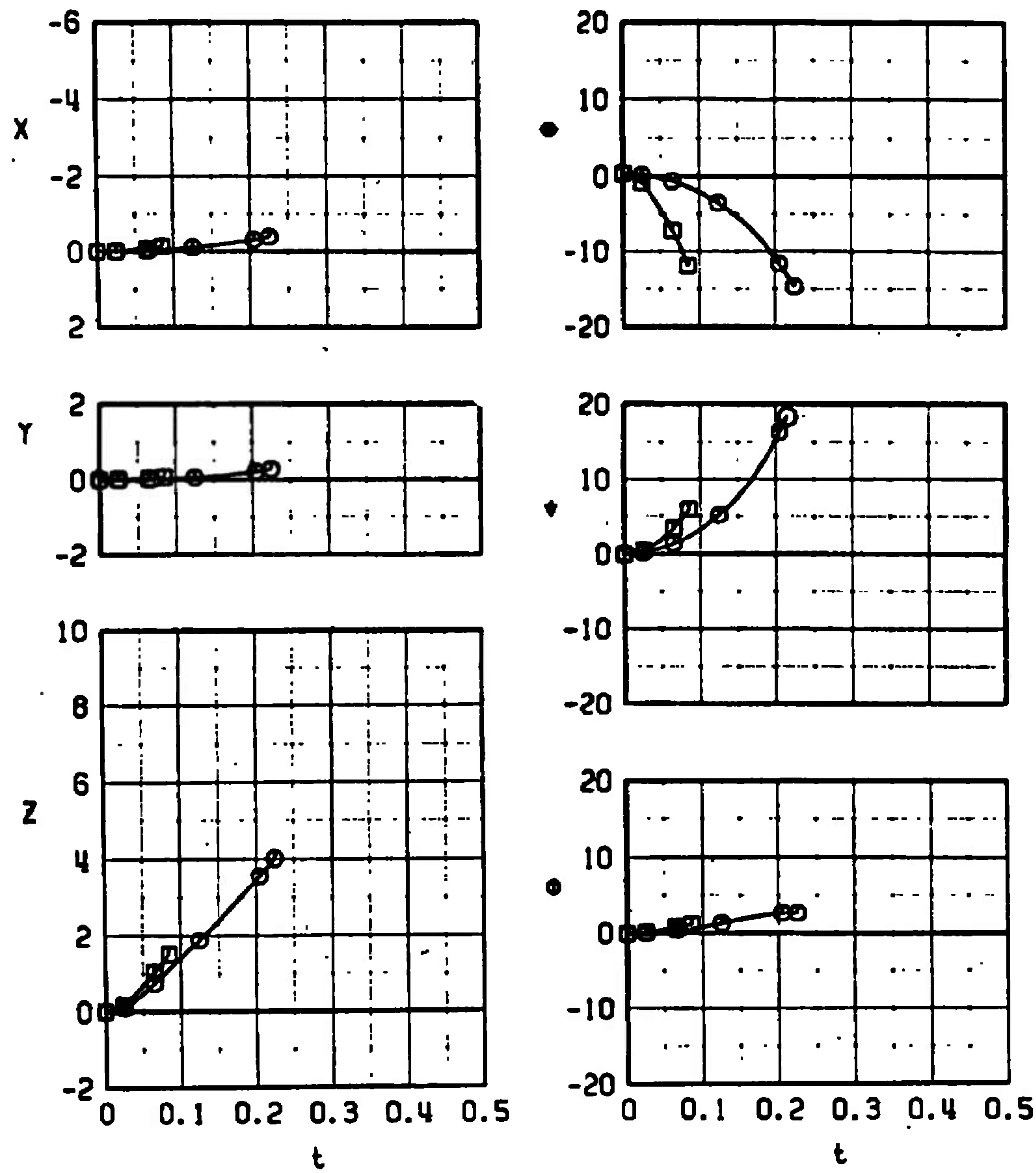
a. $M_\infty = 0.46$

Fig. 14 Effect of Store Weight on the Trajectory of the ALE-38 Chaff Dispenser when Ejected from the F-4E Aircraft, Configuration 4



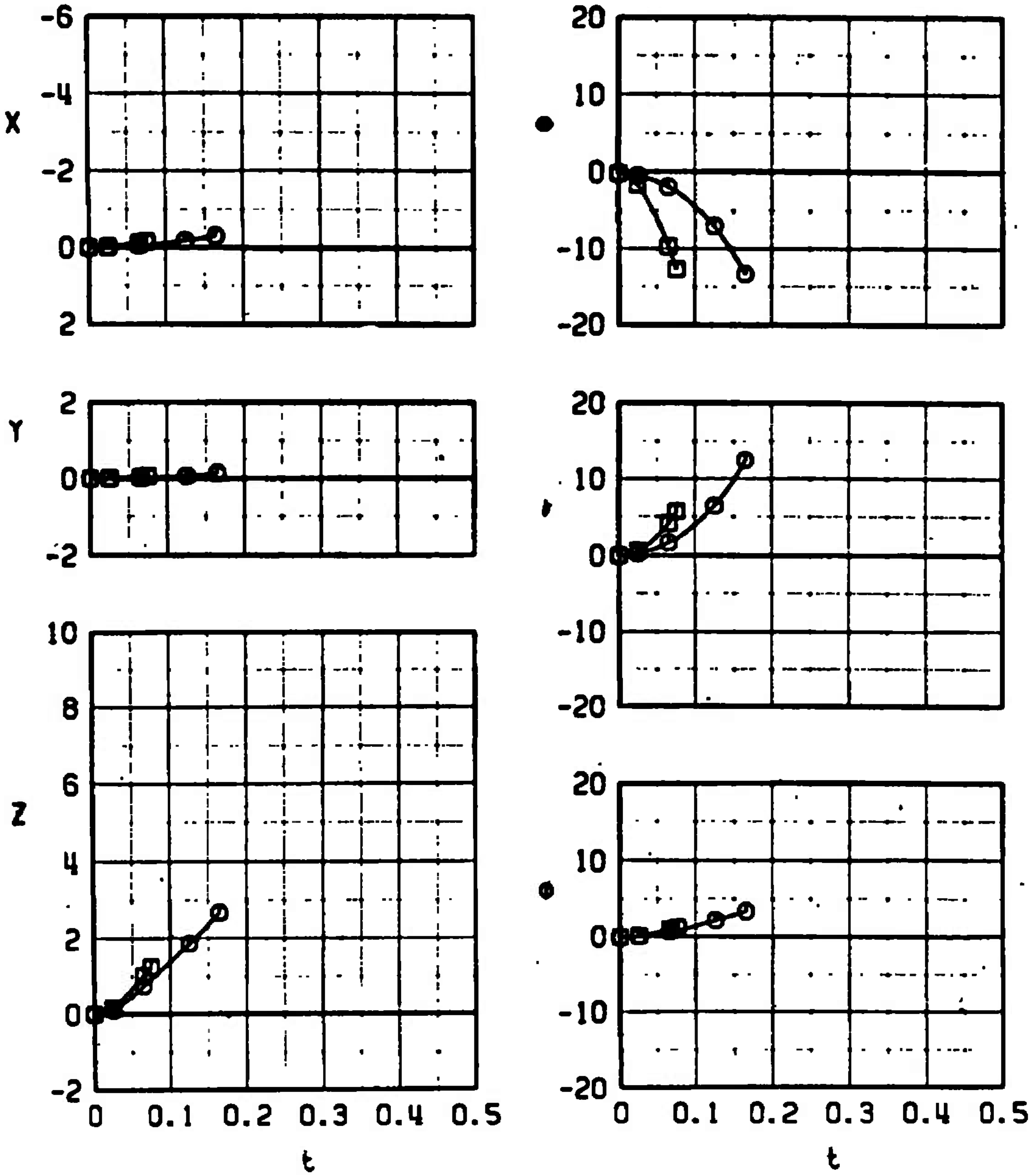
b. $M_\infty = 0.56$
Fig. 14 Continued

SYMBOL	M_∞	α_p	m
□	0.66	1.4	6.216
○	0.66	1.4	14.763



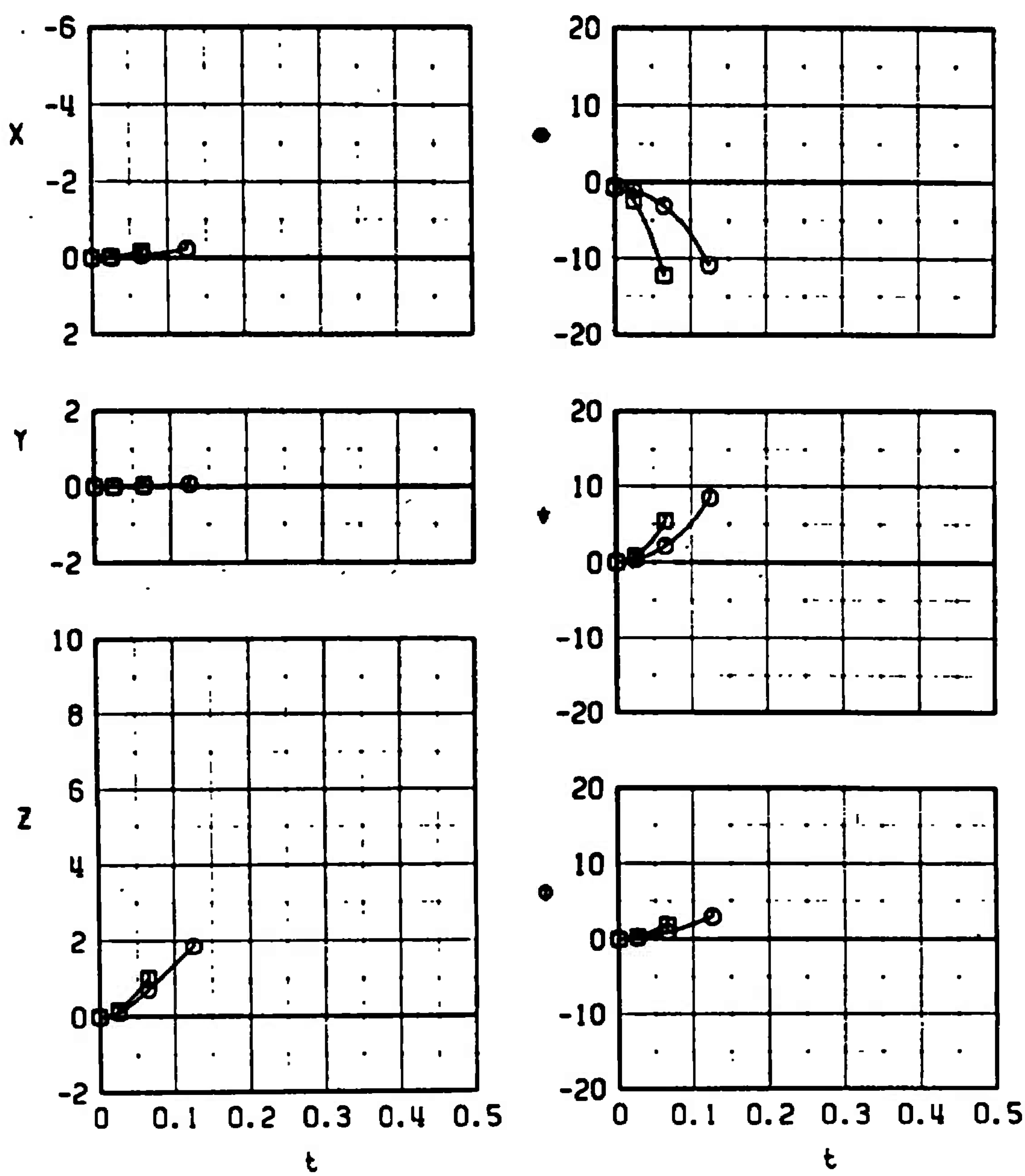
c. $M_\infty = 0.66$
Fig. 14 Continued

SYMBOL	M_∞	α_p	m
□	0.74	0.8	6.216
○	0.74	0.8	14.763

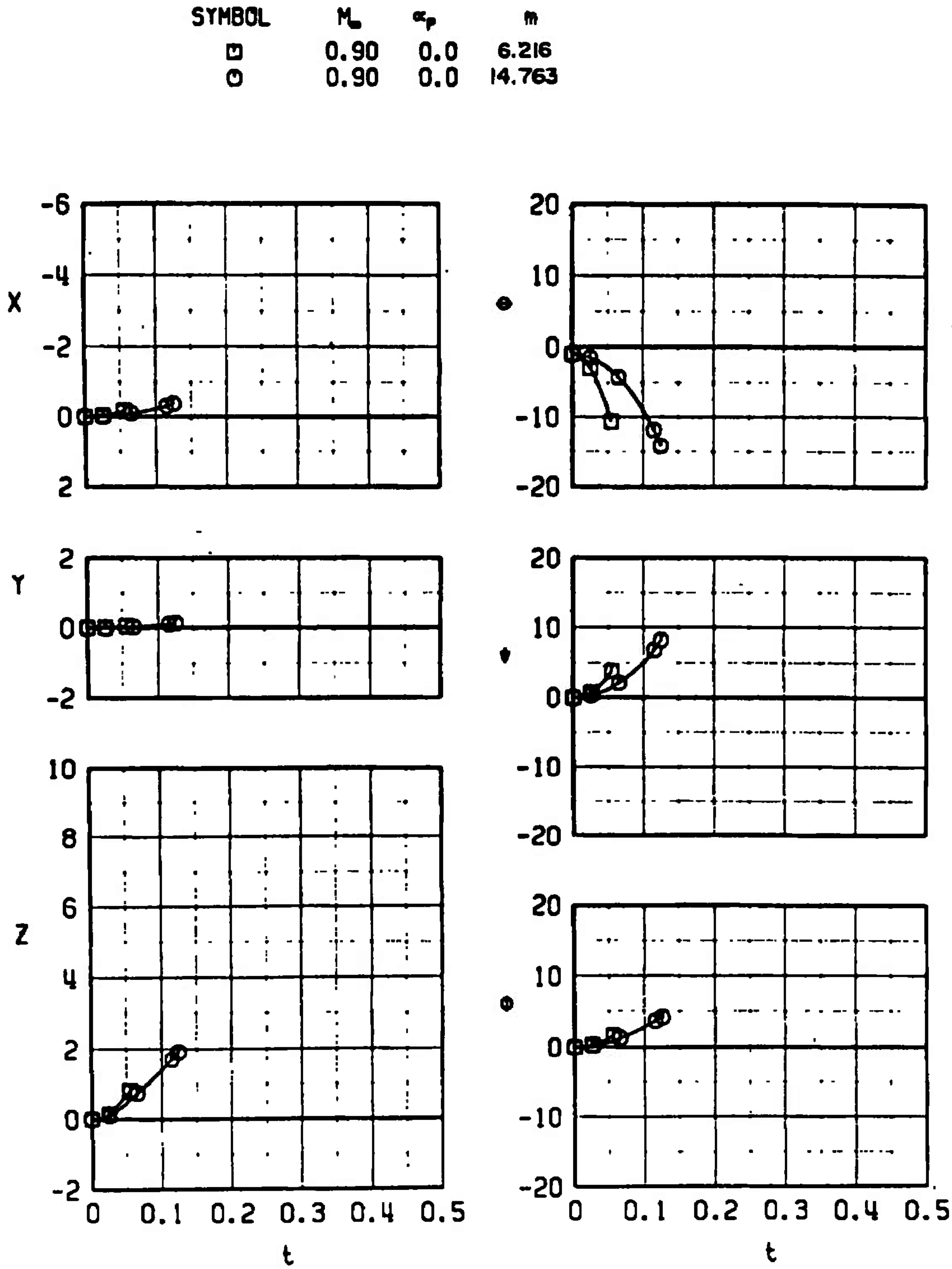


d. $M_\infty = 0.74$
Fig. 14 Continued

SYMBOL	M_∞	α_p	m
□	0.82	0.4	6.216
○	0.82	0.4	14.763



e. $M_\infty = 0.82$
Fig. 14 Continued



f. $M_\infty = 0.90$
Fig. 14 Concluded

TABLE I
AIRCRAFT/WEAPONS LOADING CONFIGURATION

Configuration	Aircraft	Centerline Station	Inboard Station	Outboard Station
1	F-4C	Clean	ALE-38	370-gal Fuel Tank
2	F-4C	600-gal Fuel Tank	ALE-38	Pylon
3	F-4E	Clean	ALE-38	370-gal Fuel Tank
4	F-4E	600-gal Fuel Tank	ALE-38	Pylon

TABLE II
FULL-SCALE STORE PARAMETERS USED IN TRAJECTORY CALCULATIONS

Parameter	Empty Store	Full Store
m, slugs	6.216	14.763
X_{cg}, ft	6.060	5.477
X_{L_1}, ft	1.353	0.770
X_{L_2}, ft	-0.314	-0.897
S, sq ft	2.095	2.095
b, ft	1.633	1.633
I_{xx}, slugs-sq ft	1.740	3.825
I_{yy}, slugs-sq ft	43	100
I_{zz}, slugs-sq ft	43	100
C_{m_q}, per radian	-34	-34
C_{n_r}, per radian	-34	-34
C_{ℓ_p}, per radian	0	0

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13 ABSTRACT

A test was conducted in the Aerodynamic Wind Tunnel (4T) to investigate the separation characteristics of the ALE-38 chaff dispenser from the F-4C and F-4E aircraft. Captive-trajectory store-separation data were obtained for four aircraft/weapons loading configurations with store separations from the right-wing inboard pylon of the F-4C and F-4E aircraft. Data were obtained at Mach numbers from 0.42 to 0.90 at a simulated altitude of 5000 ft. At each test Mach number, data were obtained for both full and empty simulated store-model weights. The data obtained show that separation without parent-to-store model contact was achieved at all test conditions.

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14. KEY WORDS	LINK A		LINK B		LINK C	
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chaff						
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transonic wind tunnels						
separation						
aerodynamic characteristics						

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Arnold AFS Tenn